AR-010-678

DSTO

A Methodology for Measuring the Physiological Strain of Enhanced Soldiers: The 1998 Soldier Combat System Enhancement Study

Denys Amos, James D. Cotter, Wai-Man Lai and Christopher H. Forbes-Ewan

DSTO-TR-0747

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

A Methodology for Measuring the Physiological Strain of Enhanced Soldiers: The 1998 Soldier Combat System Enhancement Study

Denys Amos, James D. Cotter, Wai-Man Lau and Christopher H. Forbes-Ewan

Combatant Protection and Nutrition Branch
Aeronautical and Maritime Research Laboratory

DSTO-TR-0747

ABSTRACT

The prime objective of the 1998 Soldier Combat System Enhancement Study was to assess, develop and verify methods to evaluate the physiological performance of dismounted soldiers with basic or enhanced capabilities conducting routine operations in the tropics. Core temperature, mean skin temperature and heart rate are appropriate measures for evaluating the physiological burden of soldier combat system enhancements. Current techniques for measuring mean skin temperature and heart rates are adequate. The measurement of core temperature using rectal thermistors has significant limitations, especially during vigorous activities. Studies of the hydration status of soldiers can be conducted using relatively straightforward methods to determine water intake, weight loss, urine production, and total sweat rate by weight differences. For field studies of hydration, there may be no need to analyse urine for sodium; specific gravity is more easily measured and appears to provide adequate information on hydration status. The robustness of the Metamax used for VO2 measurements was demonstrated and provided real time measurements of oxygen consumption, and of metabolic stress associated with activities.

RELEASE LIMITATION

Approved for public release

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

Published by

DSTO Aeronautical and Maritime Research Laboratory
PO Box 4331
Melbourne Victoria 3001 Australia

Telephone: (03) 9626 7000
Fax: (03) 9626 7999

AR-010-678
November 1998

APPROVED FOR PUBLIC RELEASE

A Methodology for Measuring the Physiological Strain of Enhanced Soldiers: The 1998 Soldier Combat System Enhancement Study

Executive Summary

The 1998 Soldier Combat System Enhancement Study (Phase 2 of Land125) focussed on developing analytical methods to assess the principal aspects of human factors and technology enhancements for future soldiers. The prime objective of this study was to assess, develop and verify methods to measure the physiological performance of enhanced soldiers conducting routine infantry operation in the tropics. The study was conducted at the High Range Training Area (HRTA) and Land Command Battle School (LCBS) at Tully in northern Queensland. Three clothing systems were evaluated for their impact on physiological strain: the standard Disruptive Pattern Combat Uniform (DPCU), the prototype Chemical Biological Combat Suit (CBCS) and Combat Body Armour (CBA). During the fighting patrol, observation post and assault operations, various indices of thermal strain were measured: body core temperature, skin temperature, heart rate, work rate and hydration status. The performance of enhanced soldiers in CBA and in CBCS was compared with that in DPCU.

Core temperature, mean skin temperature and heart rate were determined to be appropriate measures for evaluating the physiological burden of soldier combat system enhancements. Current techniques for measuring skin temperature and heart rate are adequate; measurement of core temperature using rectal thermistors has significant limitations, especially during vigorous activities such as assaults. Studies of the hydration status of soldiers can be conducted using relatively straightforward methods. Water intake, weight loss, urine production and total sweat rate can be determined simply by weight differences. In field studies of hydration there appears to be no need to analyse urine for sodium; specific gravity is easily measured and provides adequate information on hydration status.

Wearing CBA in hot/dry climates may increase total sweat rate and therefore water requirements but may not add significantly to the heat strain of soldiers. Wearing CBA during operations in hot/wet climates may increase water requirements and heat strain in soldiers. Wearing CBCS may not add to the thermal strain of soldiers operating in hot/dry climates; the effects of wearing CBCS in hot/wet climates need to be investigated.

Several recommendations for future trials arise from the study. Because of the nature of many physiological indices of strain, it is imperative that experimental conditions are replicated as fully as possible between treatments. This requires more use of laboratory trials to evaluate soldier combat system enhancements. Balanced order, within-subjects experimental designs are necessary to minimise the impact of non-quantifiable, confounding factors (carry-over effects and day-to-day differences in

levels of environmental or metabolic stress). It is of paramount importance that scientists and commanders agree on the scientific protocol to be followed in future studies of Land125. This protocol should not be varied without the agreement of both parties. In particular, there should be prior agreement on and commitment to, key experimental parameters (time of day, duration, route and speed of patrol) by both organisations. There must be discussion between DSTO and the Section commander during the course of the experiment and the role of a Subject Matter Expert should be expanded to maximise standardisation of the task. A DSTO observer should be included within trials to minimise data loss and document experimental details.

For improved measures of thermal strain, the development of alternative indices for core temperatures (gastrointestinal radio pill, insulated skin temperature) should be hastened. The DSTO observer can be used to conduct regular thermometry checks, especially following physically vigorous events. For heart rate measurements, hard-wired output or individualised frequency in the telemetry should be investigated. The effects of soldier enhancement on indices of physiological strain can be measured by using time averaging across the entire operation, or by using change scores between selected events, eg. onset and completion of task. Time averaging can be suitable for variables that change rapidly or are sensitive to factors that are not constant and outside experimental control. Absolute values of parameters are often not suitable for evaluating differences in strain imposed by different treatments but are essential for revealing actual levels of the physiological burden experienced by soldiers and should be used in conjunction with time averaging or change scores.

Authors

Denys Amos
Combatant Protection and Nutrition Branch

Denys Amos graduated from the University of Durham (UK) in 1960 with a BSc(Hons) and MSc (1961) in organic chemistry. He has worked with ICI and the Science Research Council and has been attached to CBDE in the UK. At AMRL he has undertaken extensive research into the decontamination and into protection of personnel against toxic chemicals. At present he is a Principal Research Scientist and manager of a program on combatant performance in the tropics. Recently he has been the principal investigator into the physiological assessment of soldier performance in the tropics and the newly developed Chemical, Biological Combat Suit.

James D. Cotter
Combatant Protection and Nutrition Branch

Jim Cotter graduated from the University of Otago (NZ) with a BSc in Physiology (1988), BPhEd in Kinesiology (1989) and MPhEd (1992) in physiological and epidemiological aspects of hypothermia. He moved to Australia (1993) and graduated from the University of Wollongong with a PhD in thermal physiology (1998). He was a lecturer (1997: physiology and exercise physiology) at the University of Wollongong, before joining the Task on Combatant Performance in the Tropics in CPNB as a Research Scientist (1998) to examine thermal strain aspects of personnel protection and performance.

Wai-Man Lau
Combatant Protection and Nutrition Branch

Tony Lau graduated in Hong Kong in 1979 in Biology and Biochemistry and obtained his M. Phil in environmental biology in 1981. Supported by a Croucher Foundation Scholarship (HK), he studied environmental toxicology at Melbourne University and was awarded a Ph.D. degree in 1987. After a short spell of employment as a senior chemist with Unipath Pathology Laboratory he jointed MRL in 1985 and conducted pharmacological studies leading to improved prophylaxis and therapy of nerve agents. He is currently a Senior Research Scientist involved in environmental physiology research and he was a member of a team to review human sciences activities and capabilities in DSTO.

Christopher H. Forbes-Ewan
Combatant Protection and Nutrition Branch

Chris graduated BSc (Hons) from ANU in 1972. Trained as a biochemist, he has more than 25 years experience in food science and physiology. Since 1986 Chris has been Senior Nutritionist at the Defence Nutrition Research Centre. From 1986 until 1994 he led a team that conducted extensive research into food acceptability, food intake and energy expenditure. Since 1994 he has conducted R&D into ergogenic aids - means of enhancing physical performance. He has also devised new ration scales for ADF use. His areas of research interest have recently expanded to include hydration.

Contents

1. Introduction

Soldier training and combat often involve a large number of young and relatively fit individuals performing high physical work loads. While these work requirements may, in themselves, lead to heat-related illnesses, it is less well recognised that even moderate levels of heat strain reduce physiological performance, through detrimental effects on metabolism, digestion, hydration and cardiovascular functions. The problem can be complicated by combined requirements of military operations in hot and humid environments of Northern Australia, and by high thermal load imposed from wearing military systems. Thus, the development of soldier combat systems enhancements must consider the physiological implications of such enhancements.

Clearly, there is a need for simple and valid methods to quantify the physiological status of soldiers in the field. This would facilitate the identification of critical deficiencies of combat systems which may impose an unsustainable physiological burden on individuals, and also provides the means by which soldiers can be monitored during routine operations. Both outcomes would benefit the combat soldier's operability and sustainability.

The 98 Soldier Combat System Enhancement Study (Phase II of Land125) focuses on developing analytical methods so that the principal aspects of human factors and technology enhancements for future soldiers can be assessed. The prime objective of this study was to assess, develop and verify methods to evaluate the physiological performance of dismounted soldiers, with basic or enhanced capabilities, conducting routine infantry operations in the tropics. The methods involved the collection and analysis of physiological data, including body core and skin temperatures, sweating rate, heart rate and oxygen consumption, of a section of soldiers during military operations in open and close country.

The study provided an opportunity to evaluate provisionally the impacts of system enhancement and environmental stress on military personnel operating in tropical conditions. Secondary objectives of the trial were a comparison of the physiological strains imposed by different protective clothing systems, compared to the Disruptive Pattern Combat Uniform (DPCU). The study was conducted at both the High Range Training Area (HRTA) in Townsville and the Land Command Battle School (LCBS) at Tully, in Northern Queensland, during February 1998. While both locations involved tropical weather conditions, HRTA provided an open country, hot/dry environment[1], whereas LCBS provided a closed country, hot/wet environment.

[1] Although HRTA was chosen as a 'hot/dry' environment, in fact relative humidity was moderate. It is only in comparison to LCBS, where relative humidity was extremely high, that HRTA could be considered to be 'hot/dry'.

2. Methods

2.1 Subjects

Ten male soldiers, comprising a Section within C Company, 1st Battalion Royal Australian Regiment (1RAR), 3 Brigade, volunteered to participate in the study. After soldiers were briefed on the objectives of the study, the potential risks of participation, and their right to withdraw, they provided informed consent to participate. The study conformed to the ethical clearance granted by the Australian Defence Medical Ethics Committee.

Soldiers had returned from the Christmas holiday period ten days before the first trial, and were therefore unlikely to have been acclimatised fully during the experiments. Peak aerobic power was initially determined, for each soldier, using a stepped-work protocol, on an electromagnetically-braked cycle ergometer (Lode Excalibur, Netherlands) at James Cook University (JCU). The protocol involved an initial workload of 50 Watts at a cadence of 60 rpm, incrementing by 50 Watts every 2 minutes until volitional exhaustion. Oxygen consumption was calculated on-line (QMC, Quinton Instruments Co., USA) every 5 seconds, and $\mathbf{V_{O2peak}}$ was taken as the highest reading. Since the mean, maximum aerobic power of soldiers would be 6-10% higher than the $\mathbf{V_{O2peak}}$ attained on the cycle, or ~ 55.5 ±6.3 $mL{\cdot}min^{-1}{\cdot}kg^{-1}$, it is considered that the present soldiers have greater aerobic fitness than their age matched civilians (44-51 $mL{\cdot}min^{-1}{\cdot}kg^{-1}$), though lower fitness than elite endurance athletes (~ >66 $mL{\cdot}min^{-1}{\cdot}kg^{-1}$). Notably, the levels measured within this one section of dismounted soldiers ranged from sedentary to highly-trained fitness.

Table 1: Characteristics of soldiers.

Soldier	Age (yrs)	Height (cm)	Mass (kg)	HR_{peak} ($b{\cdot}min^{-1}$)	V_{O2peak} ($L{\cdot}min^{-1}$)
S1	27	175.0	79.6	181	51.5
S2	22	164.8	73.4	192	48.7
S3	26	172.7	70.8	181	42.0
S4	21	178.4	75.8	201	51.2
S5	22	186.0	84.6	189	60.1
S6	23	173.2	77.5	Na	46.7
S7	24	175.7	70.4	182	51.0
S8	19	171.7	68.1	185	51.1
S9	20	183.0	91.2	178	49.5
S10	20	170.4	70.2	179	62.2
Mean	**22.4**	**175.1**	**76.2**	**185.3**	**51.4**
S.D.	**2.6**	**6.2**	**7.3**	**7.5**	**5.9**
Range	**8.0**	**21.2**	**23.1**	**23.0**	**20.2**

HR_{peak} and V_{O2peak} refer to the highest heart rate and rate of oxygen consumption, respectively, obtained during an incremental exercise test to exhaustion on a cycle ergometer. The latter is a direct measure of aerobic fitness.

2.2 Experimental Protocol

2.2.1 HF1-HF4, HRTA

The route, schedule, and activities of experiments were determined by DSTO and C Company. However, the route for Experiment HF1-HF4 at HRTA required changing on the day before the first trial, due to inaccessibility of part of the original route resulting from heavy rainfall. The total distance of the route (Appendix 1) for this experiment was shortened from the original route because of concerns about potential for heat exhaustion. The schedule of each trial in Experiment HF1-HF4 is given in Table 2.

Table 2. Schedule of Trials in Experiment HF1-HF4 at HRTA[2].

Schedule	Activities
0445-0615	Obtain weights of soldiers and their ensembles; instrument with temperature and heart rate equipment; record water consumption and collect urine samples
0630-1000	Patrol a defined route of 6 km in open country
1000-1100	Set up an observation post; collect urine samples; obtain mass of soldier and ensemble system.
1100-1130	Assault an enemy position on higher ground
1130-1135	Return to base
1135-1300	De-instrument the soldiers; obtain weights; collect urine samples

Three clothing configurations were evaluated for their impact on physiological strain:

1. The standard issue Disruptive Pattern Combat Uniform (DPCU);
2. The prototype Chemical and Biological Combat Suit (CBCS); and
3. Prototype Combat Body Armour (CBA), worn over the DPCU, without ceramic plates,.

A fourth treatment condition, comprising a new fluid delivery system (SportTank® water bladder), was also investigated within trials HF1-HF4 at HRTA, hence the need for four trials. Because that investigation was extrinsic to the objectives of this methodology, the data from that treatment are not included within this report.

[2] Because these experiments were conducted within a wider methodological study, involving several sections of dismounted soldiers, the term 'Human Factors' (HF) is used to denote the section used for these experiments. Therefore, HF distinguishes the present experiments from those conducted by other scientists.

A Latin square design was used to assign soldiers to treatment conditions, so that the impact of order effects, e.g. environmental stress, residual hypohydration or fatigue, would be minimised. Table 3 shows the sequence of treatment conditions for each soldier.

Table 3: Configuration of treatment conditions for each soldier in Experiment HF1-HF4 at HRTA.

Soldier	Role	HF1	HF2	HF3	HF4
S1	CO	DPCU+bottle	CBA+bottle	CBCS+bottle	DPCU+bladder
S2	Gunner 2	DPCU+bottle	CBA+bottle	CBCS+bottle	DPCU+bladder
S3	Rifleman 2	DPCU+bottle	CBA+bottle	CBCS+bottle	DPCU+bladder
S4	Signaller	DPCU+bladder	CBA+bottle*	DPCU+bottle*	CBCS+bottle
S5	2IC	DPCU+bladder	DPCU+bottle	CBA+bottle	CBCS+bottle
S6	Gunner 1	CBCS+bottle	DPCU+bladder	DPCU+bottle	CBA+bottle
S7	Scout 1	CBCS+bottle	DPCU+bladder	DPCU+bottle	CBA+bottle
S8	Rifleman 3	CBA+bottle	CBCS+bottle	DPCU+bladder	DPCU+bottle
S9	Rifleman 2	CBA+bottle	CBCS+bottle	DPCU+bladder	DPCU+bottle
S10	Scout 2	CBA+bottle	CBCS+bottle	DPCU+bladder	DPCU+bottle

* This sequence, which occurred accidentally, is the only deviation from a Latin square design.

2.2.2 HF5 & HF6, LCBS

Only two treatment conditions were investigated during Experiment HF5 & HF6 at LCBS. Specifically, the physiological burden imposed by wearing the CBA over the DPCU, was evaluated against that of wearing the DPCU alone, during a reconnaissance patrol. The water bladder system was used for hydration during these patrols.

The patrol route for Trials HF5 & HF6 (see Appendix 2) was approximately 9.2 km, covering undulating terrain mostly on four-wheel drive track, but also a limited distance on single track and gravel road. The majority of the route was under a closed, jungle canopy. Similar to the HF trials at HRTA, these trials started early in the day (~ 0630), so that soldiers were not working under the maximum daily environmental heat stress. The schedule of each trial is given in Table 4, and the sequence of treatment conditions for each soldier is given in Table 5.

Table 4: Schedule of each Trial (HF5 & HF6) at LCBS.

Schedule	Activities
0445-0615	Obtain weights of soldiers and their ensembles; instrument with temperature and heart rate equipment; record water consumption and collect urine samples
0630-0645	Transit to patrol start site
0645-0850	Patrol along a defined, open track of approximately 9.2 km, in close country, and return to base
0850-1000	De-instrument the soldiers, obtain weights; collect urine samples

Table 5: Configuration of treatment conditions for each soldier in HF5 & HF6 at LCBS.

Soldier	Role	HF 5	HF 6
S1	CO	CBA	DPCU
S2	Gunner 2	CBA	DPCU
S3	Rifleman 2	CBA	DPCU
S4	Signaller	CBA	DPCU
S5	2IC	CBA	DPCU
S6	Gunner 1	DPCU	CBA
S7	Scout 1	DPCU	CBA
S8	Rifleman 3	DPCU	CBA
S9	Rifleman 2	DPCU	CBA

2.3 Apparatus and Procedures

2.3.1 Oxygen Consumption (V_{O2})

A portable metabolic test system (Metamax®, Cortex, Germany) was used for the measurement of V_{O2}. Before the start of each experiment, the CO_2 and O_2 sensors were calibrated using a standard gas mixture of 6.02% CO_2 and 15.94% O_2 with nitrogen comprising the balance, and using ambient air, assuming a composition of 20.93% O_2, 0.04% CO_2 and 79% N_2. The volume transducer was calibrated according to recommended procedures, using a standard 6 L syringe. After each trial the volume transducer, wind-shield for the transducer, and the face mask, were deep-disinfected in Cidex® for at least two hours, then rinsed thoroughly with water.

The V_{O2} of only one soldier was measured within each trial. The soldier was selected on the basis of having the median aerobic fitness from within the section. At HRTA, the measurements covered the first 30 min of the patrol phase and the first 30 min of the attack phase. At LCBS, the V_{O2} was continuously measured after the patrol commenced and lasted until the soldier elected to stop.

2.3.2 Body Temperatures

Deep body temperature was measured rectally, using a flexible thermistor (YSI type 401, Yellow Springs Instruments, Ohio, USA) inserted by the soldier, 10 cm beyond the external anal sphincter. Rectal thermistor leads were fitted with a bulb, made of Araldite epoxy, approximately 9 cm from the thermistor tip, to reduce dislodgment of the lead from the rectum during trials. As further precaution against dislodgment, tape was wound around the lead after insertion, then fastened around the soldier's buttocks.

Skin temperature was measured from thermistors (Edale Instruments, Cambridge, U.K.), fastened by strapping tape (Leukoplast) at three, shaved sites; scapula, forearm and calf. Area weighted mean skin temperature was later derived using Burton's formula (Burton 1956):

$$\text{Mean Skin Temperature } (T_{msk}) = 0.50\ T_{chest} + 0.16\ T_{forearm} + 0.34\ T_{calf}\ \text{[EC]}.$$

Hard-wired logging was used to collect and store temperature data in the field, prior to down load to portable PC at the completion of each trial. The logger used in the drier environment of HRTA (experiments HF1-HF4) was a Squirrel (1206 series, Grant Instruments Ltd, U.K.), which averaged the temperatures each minute. The logger used in the wetter environment of LCBS (HF5-6) was a Trend Logger (ACR), which sampled temperatures at two minute intervals.

2.3.3 Heart Rate

Heart rate was recorded at 1 minute intervals from the R-wave frequency of ventricular depolarisation (Polar SportTester®). The transmitter was fastened around the soldier's torso, and the receiver was typically insulated from physical harm, before being placed in a breast pocket in the DPCU or CBCS. Heart rate data were down loaded to a portable PC at the completion of each trial.

2.3.4 Hydration

Soldiers presented to the preparation area approximately two hours before the activity began. Each soldier had either voided his bladder into a 500 mL screw-top specimen container on arising, or did so on arrival at the preparation area. Urine samples were retained, packed in water ice, for later dispatch to the laboratory.

Soldiers were weighed in briefs (semi-nude), in uniform (DPCU, CBCS or CBA) and in full patrol order (including all instrumentation). Magazines and full water containers to be taken into the field were weighed. Soldiers' water consumption between the time of initial weighing and the start of the activity was noted by the weight difference of one specified water bottle. Each soldier was issued with a 500 mL specimen container which was used to void the bladder (if necessary) during the first phase of the activity.

For experiments HF2 to HF4, breakfast was eaten following the initial weighing and before commencement of the patrol. Each soldier's food intake was estimated by noting the breakfast components eaten, and determining a mean weight for each component.

Start and finish times were recorded for each phase of the activity. Weight in full patrol order was noted at the observation post (OP). Urine was collected and empty containers were provided for the second phase. Water containers were weighed, refilled and weighed again.

After the assault, soldiers voided their bladders into specimen containers and were then weighed in the reverse order to that preceding the first phase, ie full patrol order (including instrumentation), uniform only, and semi-nude. Magazines and water containers were weighed.

All urine samples were taken to the laboratory at JCU, where their volume was determined. The samples were then frozen at -18°C. After all urine samples had been obtained from HF1-HF4, they were thawed. An aliquot of approximately 5 mL was retained and analysed for specific gravity (SG) by Unicon SG Urine Refractometer. Measurements of urine sodium concentrations (Synchron CX5 System, Beckman Instruments Inc., Fullerton, California) were also made for each urine sample. The Pathology Laboratory of the Townsville General Hospital conducted these analyses. Urine sodium and SG are indicators of hydration status — the onset of hypohydration is associated with increases in both of these values.

The protocol described above for HRTA was slightly different for LCBS, in that: (i) the magazines were not weighed; (ii) there was no water resupply to soldiers during their patrol; and (iii) all urine produced was measured for volume but not for any other parameter.

2.3.4.1 *Hydration Calculations:*

Sweat rate cannot be determined directly in the field. It can most conveniently be estimated by weight loss (disregarding the small loss in weight attributable to CO_2 production that results from energy production). Total sweat loss (Sw_{TOTAL}) over the period of each study was calculated as:

Initial nude weight - final nude weight + water intake + solid intake - urine output.

An estimate was made of the quantity of sweat lost, but not evaporated ($Sw_{nonevap}$). This was assumed to be sweat that was absorbed by the uniform of the soldier. It was therefore calculated as:

(Final clothed weight - final nude weight) - (initial clothed weight - initial nude weight).

Evaporative sweat loss (Sw_{EVAP}) was calculated as:

$Sw_{TOTAL} - Sw_{nonevap}$.

However, from observations made during the activities, some of the sweat that was lost but not evaporated may not have been retained by clothing but was lost as liquid to the environment[3]. $Sw_{nonevap}$ is likely to be underestimated by this method, while the results for Sw_{EVAP} are likely to be too high. Nevertheless, it is believed that the results give a reasonable estimate of the true values.

2.3.4.2 Hydration Parameters

Using Excel Spreadsheets, mean +/- SD was calculated for each of the following parameters:

Water intake up to the end of the first patrol (L);
rate of water intake to the end of the first patrol ($L \cdot h^{-1}$);
water intake during the assault and second patrol (L);
rate of water intake during the assault and second patrol ($L \cdot h^{-1}$);
total water intake (L);
rate of total water intake ($L \cdot h^{-1}$);
Sw_{TOTAL}(L);
rate of Sw_{TOTAL} ($L \cdot h^{-1}$);
urine production to the end of the first patrol (L);
rate of urine production to the end of the first patrol ($L \cdot h^{-1}$);
total urine volume produced (L);
rate of total urine production ($L \cdot h^{-1}$);
$Sw_{nonevap}$(L);
rate of $Sw_{nonevap}$ ($L \cdot h^{-1}$);
Sw_{EVAP} (L)
rate of Sw_{EVAP} ($L \cdot h^{-1}$);
specific gravity of urine before, during and after the experiment; and
sodium, before, during and after the experiment.

2.3.5 Environmental Thermal Stress

The ambient temperature for the HF experiments conducted at HRTA and LCBS were measured using a Metrosonic 3800 weather monitor. The wet bulb (T_{WB}), dry bulb (T_{DB}), globe (T_G) temperatures were measured, from which the wet bulb globe temperature (WBGT) index of environmental thermal stress was calculated. Wind speed was also recorded by a Met One Instruments mechanical anemometer. A summary of the weather conditions recorded at HRTA and LCBS is given in Appendix 3.

[3] Humidity was moderate at HRTA and extremely high at LCBS. Soldiers were literally dripping sweat from the time they commenced the patrol each morning until well after they had finished.

2.4 Experimental Design and Analyses

The HF experiments were fully-within, single factor, cross over designs. The experiments at HRTA (HF1-4) had four levels (DPCU+bottle, DPCU+bladder[4], CBCS, and CBA) and the experiments at LCBS had two levels (DPCU and CBA). A Latin-square matrix was used to balance the order of uniform and/or water delivery system across soldiers.

Dependent variables were analysed using their absolute values and/or their change across defined periods:

(i) Across the patrol (HF1-HF6);
(ii) Across the observation post (HF1-HF4);
(iii) Across the assault (HF1-HF4);
(iii) Across the entire operation (HF1-HF6),

where the change score was taken as the median for the final three minutes of a period, minus the median for the three minutes immediately preceding that period.

Statistical comparison of the absolute value or change score between selected pairs of conditions was performed using the Wilcoxon Rank-Sum Test (for temperatures, respiratory data and heart rates) or Students t-test (for hydration), with statistical significance set at 5% for each comparison. For example, to examine whether core temperature increased more across the patrol in the CBA than in the DPCU, the following calculation was made using all soldiers from whom the change in rectal temperature was able to be calculated for both conditions:

$\Delta T_{re}(CBA) - \Delta T_{re}(DPCU) > 0$

The paired comparisons of interest were DPCU versus CBCS and CBA (ie. basic versus enhanced clothing systems).

[4] Analysis of the effect of water delivery system was not within the objectives of this methodology, and it is therefore omitted from this report. DPCU data in this report are for the DPCU+bottle.

3. Results and Discussion

3.1 Experimental Procedures

3.1.1 HF1-HF4, HRTA

Upon completion of Trial HF1, which began at 0750 and ended at 1340, the schedule of remaining trials in Experiment HF1-HF4 was changed to begin at 0600. The move toward the cooler period of the day was imposed as a result of one soldier experiencing exhaustion while patrolling during HF1[5]. Predisposing factors for this occurrence of exhaustion were probably the combination of a heavy mass load (Gunner #2), the first prolonged activity in heat after the Christmas holidays, a relatively low aerobic fitness, the suffering of a current flu-like condition, and self administration of medication. The importance of having soldiers who are fully fit and heat acclimatised is illustrated by this incident.

There were other sources of variation between trials that acted to decrease the reliability of the physiological data. The route became shorter in distance and duration each successive day (see Appendix 1). The conduct of the assault was altered drastically in HF4, due to a prolonged flanking movement that involved considerably less heat stress to the entire section than during the three preceding trials.

3.1.2 HF5 & HF6, LCBS

There was a close replication of experimental procedures in these trials, which resulted in higher data reliability than obtained during HF1-HF4 at HRTA. Two unnecessary sources of variation were a ten minute rest period during HF5 but not HF6, due to photographs being taken, and a 10% increase in the speed of patrolling during the first third of HF6, compared with HF5. There was a clear impact of these procedural variations on many physiological variables.

3.2 Environmental Data

3.2.1 HF1-HF4, HRTA

Table 6 shows the environmental conditions during HF trials conducted at HRTA. The schedule for HF1 was slightly different from HF2-HF4. HF1 commenced approximately 90 min later than the other three experiments. As a result, soldiers exercised in a hotter part of the day. This was reflected in a higher mean T_{DB} (31.1°C) for HF1. The very high T_G (39.4°C) indicated that the soldiers were also exposed to substantial radiant heat. Of the HF2-HF4 trials, HF2 appeared to be hotter than HF3 and HF4, with higher recorded T_{DB} (30°C) and T_G (36.2°C). However, this was not

[5] It should be pointed out that the soldier who collapsed with exhaustion during HF1 was suffering from a cold, and recovered quickly, to resume his place in the section the following day.

apparent for T_{WB}. The highest T_{WB} was in HF3 (25.5°C), indicating a higher relative humidity on that day. When combined with the mean wind speed being the lowest in HF3 (0.21 m·sec^{-1}), the effectiveness of evaporative cooling was reduced markedly. Thus, according to the WBGT, environmental thermal stress appeared to be highest in HF1 (28°C), and lowest in HF4 (27.4°C). However, during all four HF trials at HRTA the WBGT exceeded 27°C; the level that would be of concern to most OH&S practitioners.

Table 6: Mean environmental conditions during the trial at HRTA.

Day	T_{DB} °C	T_{WB} °C	T_G °C	WBGT °C	Wind Speed m·s^{-1}
Day 1 (HF1)	31.1	24.2	39.4	28.0	0.82
Day 2 (HF2)	30.0	25.0	36.2	27.7	0.83
Day 3 (HF3)	29.6	25.5	35.6	27.9	0.21
Day 4 (HF4)	29.1	25.1	34.6	27.4	0.56

T_{DB} = Dry bulb temperature (°C); T_{WB} = Wet bulb temperature (°C); T_G = Globe temperature (°C); and WBGT = WBGT index (°C)

3.2.2 HF5 & HF6, LCBS

Table 7 summarises the environmental conditions during the trials at LCBS. HF5 and HF6 were conducted very early in the morning. Mean T_{DB} for the two days (24.2 and 24.4°C respectively) were similar, and both of them were only 0.2°C above the T_{WB} indicating a relative humidity of near saturation. There was little or no air movement, thus the effectiveness of evaporative cooling was extremely low. Thermal load from radiant heat was also moderate, as indicated by the relatively low T_G. No mean WBGT values exceeded the critical value of 27°C, suggesting that environmental heat stress was not rated as being of concern.

Table 7: Mean environmental conditions during trials HF5 & HF6 at LCBS.

Day	T_{DB} °C	T_{WB} °C	T_G °C	WBGT °C	Wind Speed $m \cdot s^{-1}$
Day 1 (HF5)	24.2	24.0	24.9	24.2	0
Day 3 (HF6)	24.4	24.2	27.1	24.8	0

T_{DB} = Dry bulb temperature (°C); T_{WB} = Wet bulb temperature (°C); T_G = Globe temperature (°C); and WBGT = WBGT index (°C)

3.3 Oxygen Consumption and Metabolic Rates

3.3.1 HF1-HF4, HRTA

Table 8 summarises the oxygen consumption and minute ventilation of a soldier for the activities conducted in trials HF1-HF4. These calculations use an assumption that energy is not derived from protein oxidation.

The mean oxygen consumption ranged from 1.03 to 2.44 $L \cdot min^{-1}$ on HF1, 0.9 to 2.32 $L \cdot min^{-1}$ on HF3 and 0.74 to 2.15 $L \cdot min^{-1}$ on HF4 during the fighting patrol. The rate of oxygen consumption closely followed the type of activity undertaken by the soldier during patrol. For example, climbing the 405m hill obviously required greater metabolic cost than descending. This was reflected in the greater rates of minute ventilation and oxygen consumption.

The oxygen consumption and metabolic rates of the assault phase indicated only moderate work intensity. For example, the highest oxygen consumption of 2.08 $L \cdot min^{-1}$ was recorded during the attack phase in HF2 experiment. This was equivalent to a metabolic rate of 714 watts. The result suggested that the work intensity during the attack was no more demanding than climbing the hills encountered early in the patrol.

The soldier wore different configurations in trials HF1 to HF 4 (Table 3). A direct comparison of the oxygen consumption and metabolic rates associated with each configuration was not possible. This was due to the fact that other important independent variables, such as the weather conditions, scheduling of the trials and the duration of activity of each HF experiment, were not constant between trials.

3.3.2 HF5 & HF6, LCBS

The activities for the HF experiments at LCBS, Tully were slightly different from those at HRTA. The section patrolled alongside a track with different degrees of undulation. Table 9 shows a summary of the oxygen consumption, metabolic rates and minute ventilation of a soldier conducting a reconnaissance patrol at LCBS. Again, the level of physical exertion required for a specific activity determined the oxygen consumption and metabolic rate. For example, in HF5, waiting for transport registered a consumption of only 0.83 $L{\cdot}min^{-1}$, while patrolling on steep elevations recorded 2.91 $L{\cdot}min^{-1}$. The mean metabolic rate (965 watts) for this patrolling activity was exceptionally high, suggesting that the soldier was working extremely hard.

Table 8: Summary of oxygen consumption, metabolic rate and minute ventilation of a soldier during HF1-HF4 at HRTA.

Activity	Day 1 (HF1) CBCS			Day 3 (HF3) DPCU			Day 4 (HF4) CBA		
	$sV'O_2$	Metabolic Rate	V'E	$sV'O_2$	Metabolic Rate	V'E	$sV'O_2$	Metabolic Rate	V'E
Before OP									
Patrol	1.49	504	36.14	1.54	524	35.70	1.29	438	31.46
Ascending hill (405m)	2.44	852	67.65	2.32	810	65.95	2.07	723	56.47
Descending hill (405m)	1.29	446	39.04	1.18	415	41.48	1.18	412	35.80
Rest	na	na	na	0.90	307	28.66	na	na	na
Patrol (woodland)	1.03	349	28.51	1.06	357	28.03	1.03	351	28.51
Creek crossing	na	na	na	1.71	581	44.84	1.75	601	47.58
Patrol (woodland)	na	na	na	na	Na	na	1.33	453	34.99
Ascending hill (414m)	na	na	na	na	Na	na	2.15	751	66.47
Descending hill (414m)	na	na	na	na	Na	na	0.74	256	24.59
After OP									
Moving through woodland	1.30	na	26.94	0.55	179	10.86	0.94	318	26.36
Assault	1.60	na	48.05	1.40	467	33.87	2.01	699	65.76

$sV'O_2$ = STDP corrected O_2-intake ($l.min^{-1}$). Metabolic Rate (watts), V'E = minute ventilation ($l.min^{-1}$)

Table 9: Summary of oxygen consumption, metabolic rate and minute ventilation of a soldier conducting a fighting patrol at LBCS.

Activity		Day 1 (HF5) CBA			Day 3 (HF6) DPCU	
	SV'O$_2$	Metabolic Rate	V'E	sV'O$_2$	Metabolic Rate	V'E
Waiting for transport	0.83	253	16.88	na	na	na
Transit to patrol site	0.72	187	14.41	na	na	na
Patrol (Undulations)	2.61	856	55.01	2.41	851	73.38
Patrol (Flat land)	2.07	678	44.36	2.00	689	57.66
Rest	1.54	506	32.97	1.07	371	34.68
Patrol (Flat land)	2.00	663	43.57	1.84	615	50.37
Patrol (Gentle elevation)	2.13	708	46.39	1.30*	441	40.94
Patrol (Steep elevation)	2.91	965	62.75	2.31*	784	67.78

sV'O$_2$ = STDP corrected O$_2$-intake (L·min^{-1}); Metabolic Rate (watts); V'E = minute ventilation (L·min^{-1}).
Accuracy of measurements was decreased, as the soldier had intermittently adjusted the face mask during the last stages of the patrol because of dyspnea.

3.4 Core Temperature

3.4.1 HF1-HF4, HRTA

Figure 1 illustrates the progression of rectal temperature (T_{re}) of each soldier within one trial (HF1). Of note, there were numerous dislodgments of the rectal probe, shown in Figure 1 as low or absent values. This was more prevalent during hill climbing and the assault. Since T_{re} is a critical measure of physiological strain, an attempt was made to reduce data loss by taping the rectal probe to the buttocks during soldier preparation, and by ensuring that the DSTO observer made frequent checks on the logging status during each trial. Clearly, the loss of T_{re} data requires further attention.

Mean T_{re} at patrol onset (37.2°C) was equivalent between clothing systems (p=0.89), but not between days (p=0.0004). On average, soldiers had higher core temperature at patrol onset in HF1 (37.3°C) and HF3 (37.2°C), compared with HF2 and HF4 (37.1°C), thus highlighting the need to counter-balance the order of treatment conditions and minimise procedural

inconsistencies. The basal T_{re} appears to be slightly high for aerobically fit, heat acclimatised soldiers, early in the day. However, it was probably due to some conspicuously high T_{re} (ie. mild fever), associated with a respiratory infection, which affected most soldiers during the course of the study.

Figure 2 illustrates the progression of mean T_{re} on each day (ie. HF1-HF4). The initial rise in T_{re} is due to the onset of patrolling and movement over two hills, before patrolling on relatively flat terrain to the observation post (see Appendix 1). The gradual increase in T_{re}, that occurs from the end of the first T_{re} peak (associated with traversing the hills) until arrival at the observation post, is illustration of the `thermal drift' which normally occurs during maintained work in the heat, and is attributed mainly to progressive dehydration (Montain & Coyle, 1992; Hargreaves & Febbraio, 1998). The 50-60 minutes spent at the observation post allowed a substantial drop in core temperature, to near the resting level, prior to very high rates of heat gain during the assault. It should be noted that very high core temperatures, probably exceeding 40°C for soldiers 2 and 9 (see Appendix 5), would be anticipated if the assault had occurred without this opportunity to eliminate so much heat prior to onset of the assault.[6]

[6] Since conflicts can arise in the absence of preceding observation post rest periods, then it may be essential to specifically examine thermal strain under such conditions.

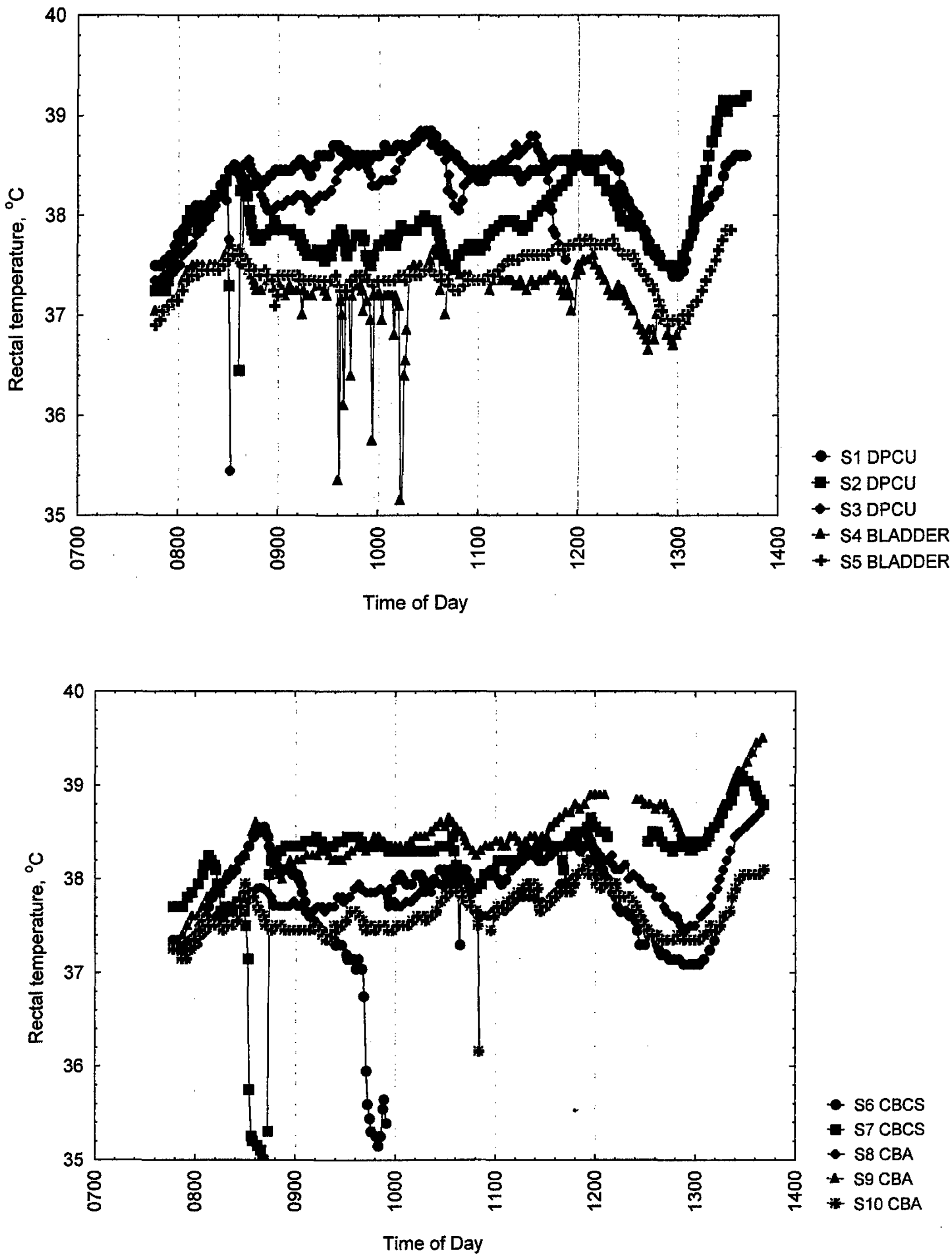


Figure 1: Rectal temperature for each soldier, as a function of elapsed time, during HF1 at HRTA. Soldiers patrolled until 1205, then remained in an Observation Post until 1300, before engaging in an assault from 1307 until 1330. See Footnote 3 for discussion of the skin temperature decrease of Soldier 3. Note the loss of data, illustrated as low or absent data points, which occurred more commonly during hill climbing and during the assault.

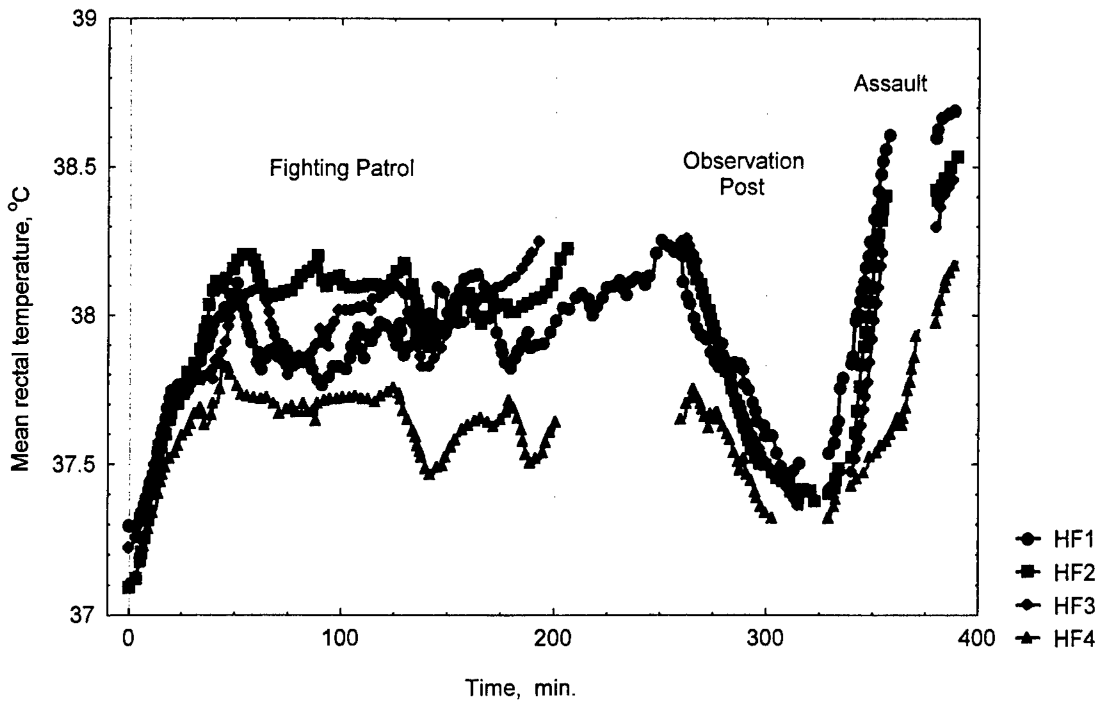


Figure 2: Mean rectal temperature as a function of time during HF trials (HF1-HF4) at HRTA. Note the differences in progression of rectal temperature between the four patrols, the substantial recovery during the observation period, and the high rates of heat gain during the assault.

Figure 2 further illustrates the extent to which T_{re} was confounded by procedural inconsistencies between days. The HF1 patrol began later, and was approximately 1 hour longer than on ensuing days, due to the longer route (see Appendix 1), and the more frequent and longer Location Schedule reports (shown as decreases in T_{re}). Also, the assault in HF4 was dissimilar to those in HF1-HF3, due to the Section Commander adopting a different assault strategy, in response to early detection of the enemy.

The notable deviation of T_{re} in the HF4 patrol from those in HF1-HF3 (Figure 2) was consistent with subjective impressions of the soldiers, and was assumed to be due to lower environmental heat stress because of the regular cloud cover on that day. However, the WBGT index did not support this assumption (see Appendix 3). Thus, the lower T_{re} may have been due to physiological adaptation to the stress imposed by the task, a possible effect of the flu-like virus being less prevalent on this day, or maybe to lower environmental stress which was not reflected by the WBGT index. The present methodology therefore highlights the need to: (i) balance the order of presentation of experimental treatment groups; (ii) restrict the number of treatment groups; and (iii) reconsider, on the basis of previous concerns (Santee & Gonzalez, 1988; Brotherhood, 1995), the use of WBGT as the measure of exogenous thermal stress.

The T_{re} response within each experimental condition is shown in Figure 3, illustrating the equivalence with which T_{re} was elevated during the patrol in the DPCU compared with the CBCS or CBA (Table 10). Because of the procedural problems outlined above, the statistical

power of these comparisons was low, which indicates that the present data cannot be used to conclude that the CBA imposes no more heat strain than is caused by the DPCU during patrols. Similarly, the T_{re} recovery during the observation period was not statistically impaired whilst wearing the CBCS or the CBA, relative to the DPCU (Table 10). The rapid rise in core temperature during the assault was also not exacerbated by the CBCS or the CBA, relative to the DPCU (Table 10). Again, the dissimilar assault in HF4 (Figure 2) and the dislodgment of rectal probes during this activity (see Appendix 5), reduced the statistical power of these comparisons.

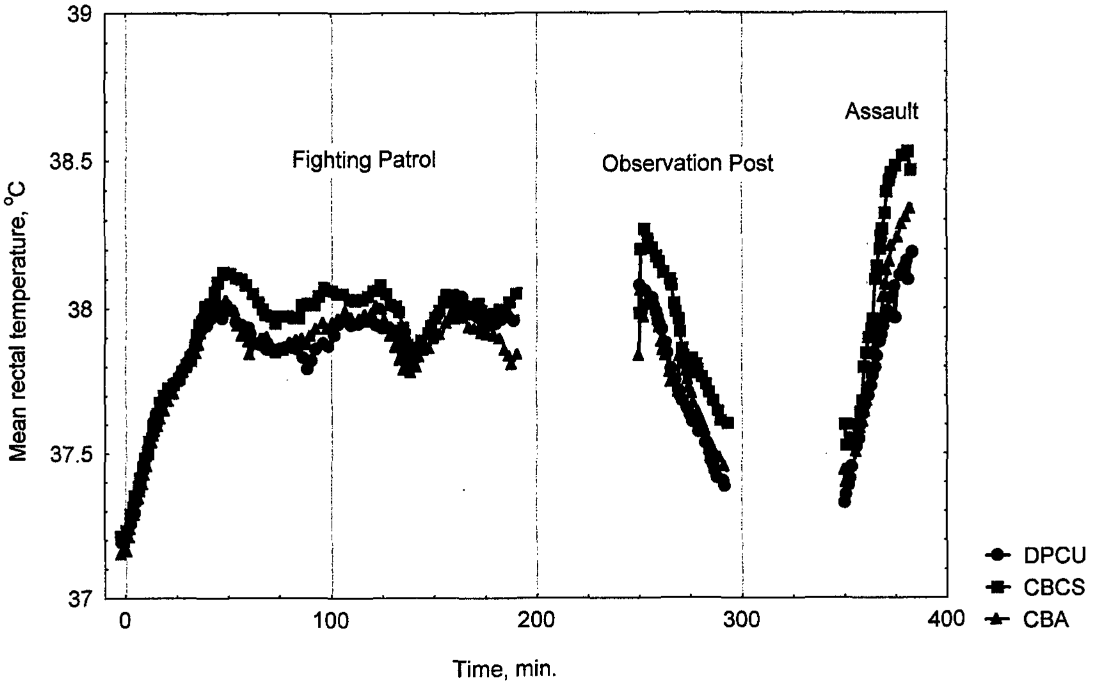


Figure 3: Mean rectal temperature for each treatment condition, as a function of time during HF trials at HRTA. The times that denote the onset of observation (250 min) and assault (350 min) periods are arbitrarily defined for the purpose of data illustration. That is, each garment type was worn on different days by different soldiers, and because durations of patrolling, observation and assault were not identical each day, it is not possible to join the data between these three periods. Progression of rectal temperature was not statistically different between treatments, across any phase of the trial (see Table 10). As discussed in the text, and shown Appendix 5, there was substantial loss of rectal temperature data periodically within trials. Therefore the mean core temperatures illustrated here for each treatment, are constructed from variable sub-sections ($n \geq 7$) of the sample (N = 10), and do not accurately represent the thermal strain imposed by each garment system.

Table 10: Mean difference in the change of rectal temperature when wearing the CBCS or CBA, compared with wearing the DPCU, during each of four phases of HF trials at HRTA.

	CBCS - DPCU		CBA - DPCU	
	Mean Diff	*p*	Mean Diff	*p*
Patrol	0.06	*0.73*	0.07	*0.73*
Observation Post	0.03	*0.86*	0.10	*0.48*
Assault	0.11	*0.34*	0.07	*0.14*
Operation	0.05	*0.71*	0.05	*0.83*

Note: The table shows that the progression of rectal temperature was statistically equivalent for each of the garment systems evaluated, during each phase of the trials. For example, while it appears that the mean increase in core temperature during the assault was 0.11C higher while wearing the CBCS than the DPCU, this difference was not statistically significant (p=0.34).

3.4.2 HF5-HF6, LCBS

The HF5-HF6 experiment allowed convenient evaluation of the physiological burden of a combat system enhancement (CBA) against the basic configuration (DPCU). That is, the configurations were presented as a cross over design (balanced order, using the same soldiers). Both trials were conducted similarly in terms of the patrol onset times (HF5 = 0646, HF6 = 0636), duration (120 min, and 105 min), route followed (both 9.2 km), and levels of environmental thermal stress (WBGT = 24.2°C and 24.8°C). Moreover, because the task involved simply marching on a four-wheel drive track there were fewer data lost from dislodgment of rectal probes than had occurred during HF1-HF4. For instance, HF5 involved some loss of T_{re} in Soldier 3, and HF6 involved substantial loss in Soldiers 3, 4 and 7.

T_{re} at patrol onset was equivalent for both patrols (HF5 = 37.4°C and HF6 = 37.4°C) and for both garment configurations (DPCU= 37.4°C and CBA = 37.4°C). Figure 4 illustrates that while the rise in T_{re} was substantial for both configurations across the patrol, it was greater for the CBA than for the DPCU alone: DPCU = +0.9°C, CBA = +1.2°C (p=0.028). Similarly, the peak difference in T_{re} elevation between configurations during the patrol was 0.6°C (p=0.028), with core temperature exceeding the Occupational Health and Safety limit of 38.5°C while wearing the CBA, but not with the DPCU alone.

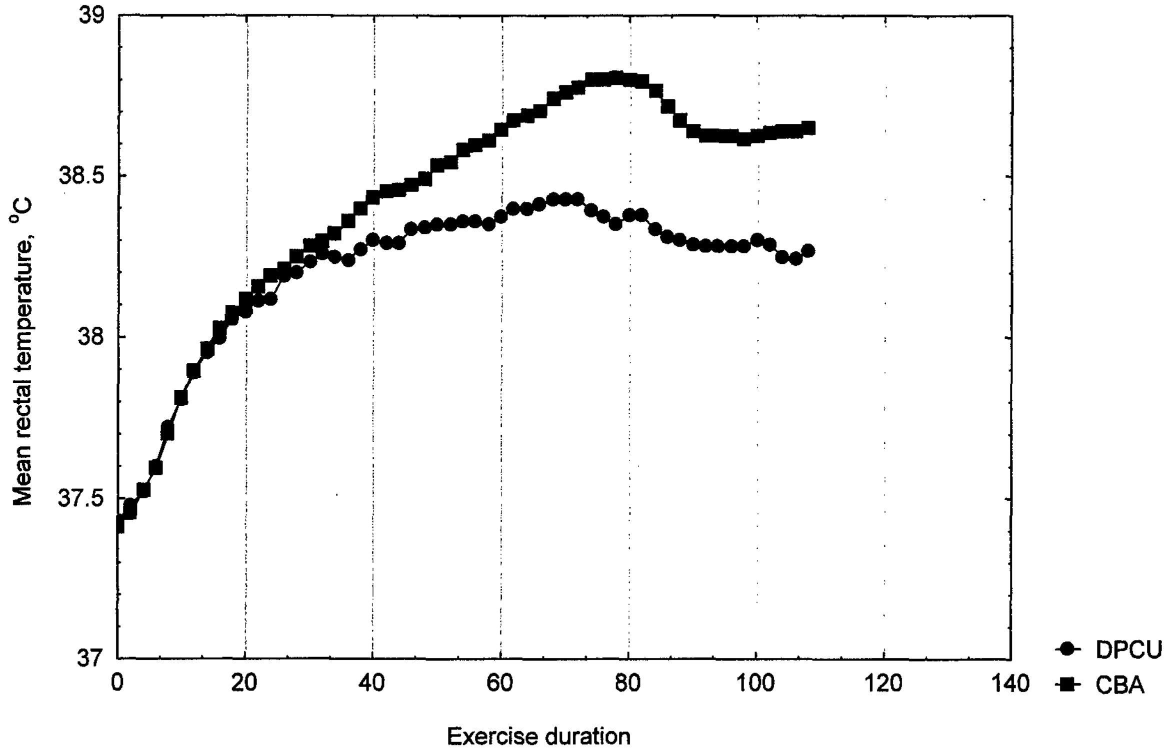


Figure 4: Mean rectal temperature as a function of elapsed time during HF patrols at LCBS. Note that heat storage was initially rapid, irrespective of whether the DPCU was worn alone or in combination with CBA, and that heat balance took longer to occur, and was at a higher level (by 0.6°C, p=0.028), in the CBA.

In summary, measurement of T_{re} was occasionally ineffective, particularly during vigorous activity. Nevertheless, the strain on deep body temperature, as indexed from T_{re}, was observed to be higher when the CBA was worn additionally to the DPCU during a reconnaissance patrol (at LCBS). This extra thermal burden of the CBA was not observed for a fighting patrol, observation period, or an assault (at HRTA). Two reasons probably contributed to the difference being observed at LCBS, but not at HRTA. Firstly, the marching patrol created a sustained, high level of thermal stress, which was particularly conducive to revealing the extra thermal strain of the CBA. Secondly, and more importantly, several aspects of the design and execution of the experiment at LCBS (HF5&HF6) were superior to that at HRTA (HF1-HF4).

3.5 Mean Skin Temperature

Mean skin temperature (T_{msk}) is used in conjunction with T_{re} to indicate the level of, or change in, body heat content. Also, when examined across individuals or garment systems, a lower T_{msk} usually indicates better maintenance of heat loss, and therefore less physiological burden. However, changes in skin temperature in an individual are difficult to interpret since the two physiological heat loss effector mechanisms (skin blood flow and sweating) tend to have opposing effects on T_{msk}. Increasing the skin blood flow usually increases T_{msk} by delivering heat to the skin surface, whereas increasing sweating rate tends to decrease T_{msk}, by removing heat to the environment through evaporation.

3.5.1 HF1-HF4, HRTA

Figure 5 illustrates the mean skin temperatures of soldiers in HF1, at HRTA. Soldiers 1-5 were all wearing DPCU alone, yet their mean skin temperatures differed by up to 2°C at a given time, and were, with exceptions, indicative of their underlying core temperatures (see Figure 1 and Appendices 5 and 6).[7]

Figure 6 shows the mean skin temperature, averaged across soldiers, for each treatment condition at HRTA. Fluctuations in mean skin temperature followed those of core temperature, presumably due to thermoregulatory controlled changes in skin blood flow. As had occurred for core temperatures during this experiment, there was no statistical support for the CBCS or CBA imposing greater T_{msk} than imposed by the DPCU during patrol, the observation post, the assault, or the entire operation (Table 11). However, these findings are subject to the precautions noted above for interpretation of the T_{re} comparisons.

[7] The conspicuous, sustained drop in T_{msk} of soldier 3 is noteworthy, since it mirrored the T_{re} response (see Figure 1) and preceded the soldier collapsing with exhaustion at 1155. Of particular interest, this T_{msk} progression was opposite to the convergence of T_{msk} and T_{re}, which is widely, though not universally, regarded as a signal of impending heat intolerance. From examination of this soldier's T_{re} (Figure 1), T_{msk} (Figure 5) and heart rate (see Figure 8), it seems that thermal and cardiovascular strain progressively increased until the cardiac reserve was expended, after which the skin blood flow became progressively attenuated (hence the reduction in T_{msk}), leading to excessive heat storage and exertion-related discomfort.

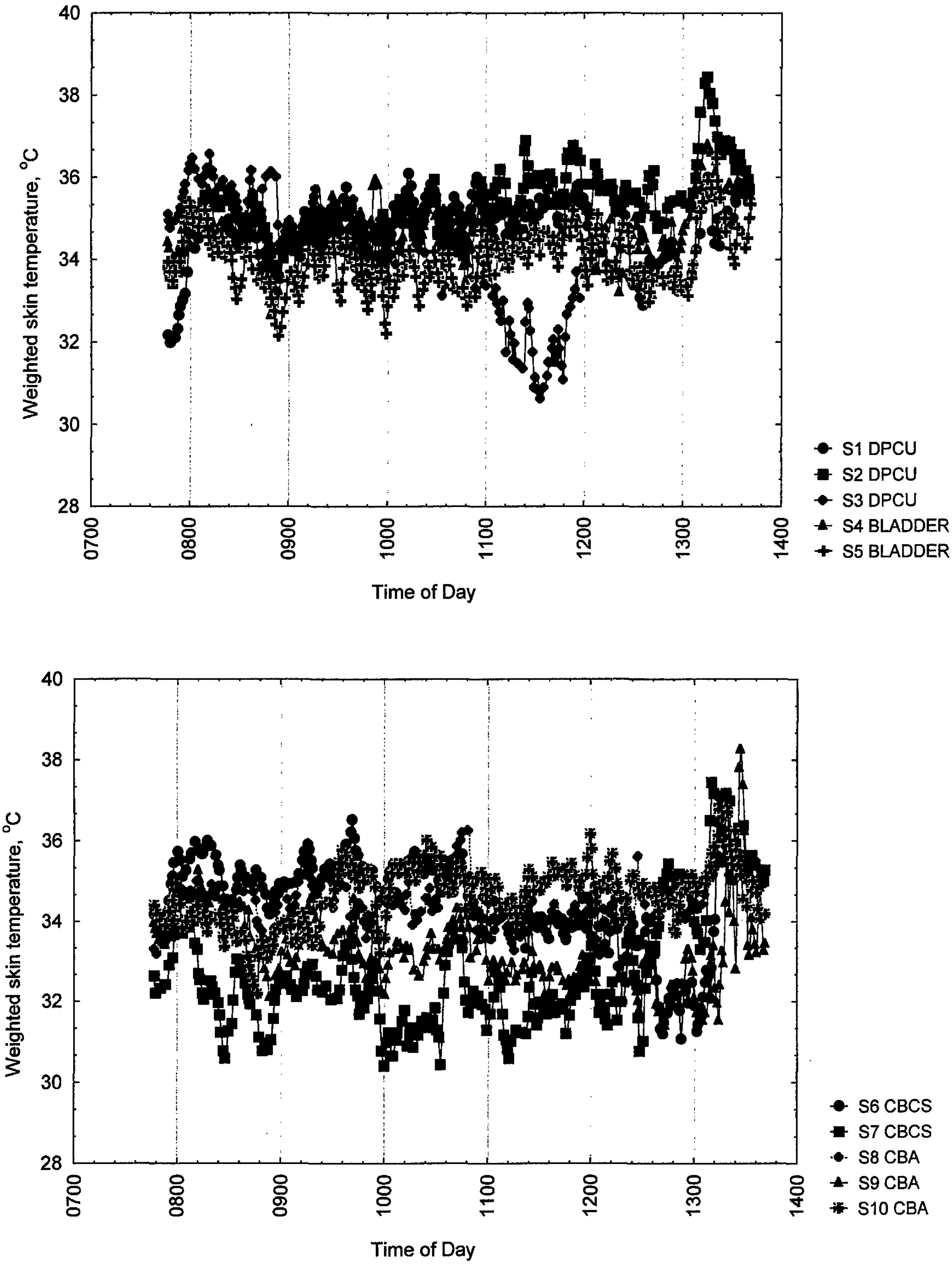


Figure 5: Mean skin temperature for each soldier, as a function of elapsed time, during HF1 at HRTA. Soldiers patrolled until 1205, then remained in an Observation Post until 1300, before engaging in an assault from 1307 until 1330. See Footnote 4 for discussion of the skin temperature decrease of Soldier 3.

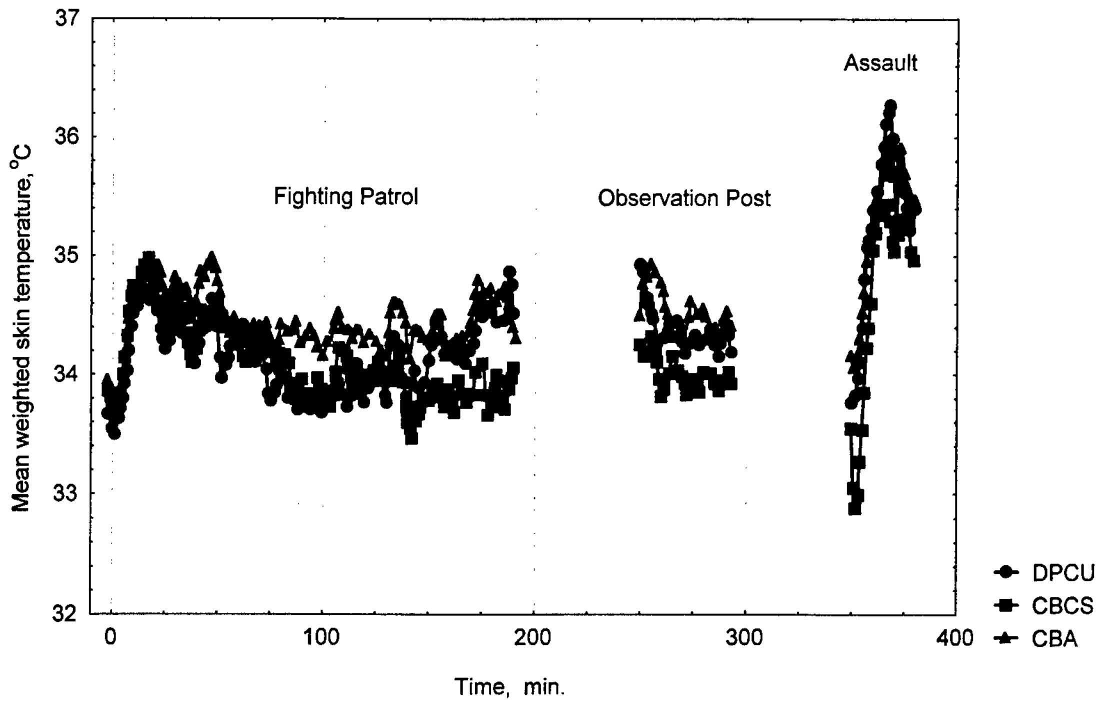


Figure 6: Average, mean skin temperature for each treatment condition, as a function of time during HF trials at HRTA. The times which denote the onset of observation (250 min) and assault (350 min) periods are arbitrarily defined for the purpose of data illustration. That is, each garment type was worn on different days by different soldiers, and because durations of patrolling, observation and assault were not identical each day, it is not possible to join the data between these three periods. Note the tendency for mean skin temperature to follow core temperature (Figure 3), and the trend for the CBCS to produce a lower mean skin temperature with progressing time. However, no statistical differences were observed between treatments (Table 11).

Table 11: Mean difference in the change of mean skin temperature when wearing the CBCS or CBA, compared with wearing the DPCU, during each of four phases of HF trials at HRTA.

	CBCS - DPCU		CBA - DPCU	
	Mean Diff	*p*	Mean Diff	*p*
Patrol	0.87	*0.63*	0.83	*0.12*
Observation Post	0.43	*0.33*	0.64	*0.17*
Assault	0.08	*0.61*	0.18	*0.51*
Operation	0.14	*0.92*	0.25	*0.40*

Note: The table shows that the progression of mean skin temperature was statistically equivalent for each of the garment systems evaluated, during each phase of the trials. For example, although mean skin temperature appeared to increase by approximately 0.85°C more whilst wearing the CBA or CBCS during patrol, compared with the DPCU, this apparent difference was not supported statistically.

3.5.2 HF5-HF6, LCBS

After approximately 6 minutes of the patrol in HF5 and HF6, the mean skin temperature increased rapidly, before gradually declining for the remainder of the patrol. The increase is probably due to an increase in skin blood flow following the initial rise in body heat content. The reduction in mean skin temperature during the patrol is attributed to a delay in the onset of sweating, and the slow development of effective evaporative heat loss through the DPCU and/or CBA (as supported by the rectal temperature data in Figure 4).

The mean difference in T_{msk} change scores between DPCU and CBA across the patrol was only 0.08°C (p=0.77), for which the tendency might be to conclude that the CBA imposed no more elevation in superficial body temperatures than was caused by the DPCU alone. However, Figure 7 reveals that T_{msk} was higher in the CBA at the onset of data collection (by 0.7°C, p=0.015), and this differential was simply maintained (to within 0.08°C) across the patrol. This point is made to highlight the need to consider both absolute values and change scores when evaluating the physiological burden imposed by combat system enhancements.

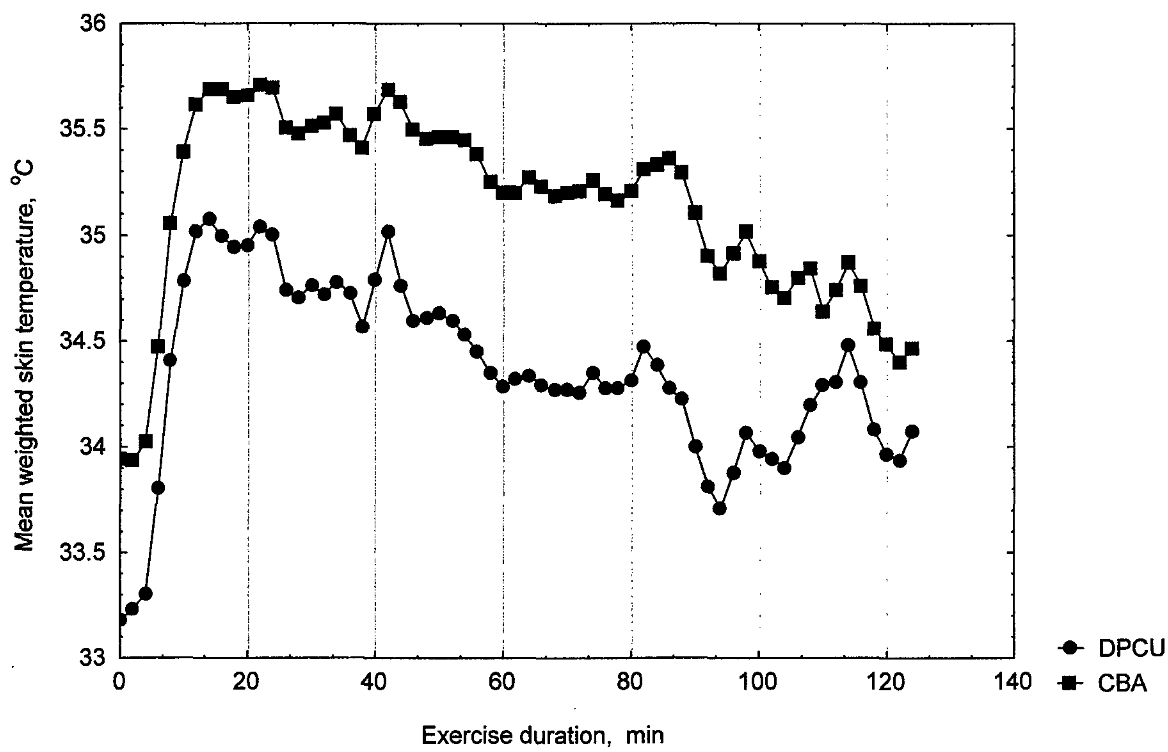


Figure 7: Average, mean skin temperature for each treatment condition, as a function of elapsed time during HF trials at LCBS. Note that skin temperature is elevated at the onset of the patrol while wearing the CBA, and this elevation is maintained a similar level for the duration of the patrol.

In summary, changes in mean skin temperature generally followed the changes in core temperature, and were considerably less problematic. When mean skin temperature was evaluated with due consideration of underlying core temperature, this variable also provided an effective measure of the additional physiological burden imposed by wearing the CBA.

3.6 Heart Rate

Heart rate is sensitive to changes in posture, arousal, dehydration, and thermoregulatory adjustments to skin blood flow. Therefore, if care is taken to evaluate heart rate over periods in which posture and arousal are standardised, it provides a useful index of the cardiovascular strain caused by a given stress (e.g. of wearing the CBA over the DPCU during patrol).

3.6.1 HF1-HF4, HRTA

The heart rate of individual soldiers during one trial (HF1) is illustrated in Figure 12. While it should be remembered that maximum heart rates differ between soldiers (see Table 1), it is also clear that some soldiers (e.g. Soldiers 5 and 10) suffered considerably lower cardiac strain than did others (e.g. Soldiers 2, 3 and 9), independently of their treatment condition. A comparison of soldier's heart rates (Figure 8) with their corresponding rectal temperatures (Figure 1) illustrates that these variables are moderately related across individuals, but are not able to be used for prediction of one from the other (ie. prediction of core temperature from heart rate).

As for rectal and mean skin temperatures, there was no statistical support for the CBCS or CBA having caused different cardiovascular strain (as indexed by heart rate) than was caused by the DPCU, during any phase of the HF1-HF4 trials (Table 12). However, Table 12 also shows that it was at least 90% probable that the CBA had imposed a mild degree of additional cardiovascular strain (compared with the DPCU alone) during the observation and assault periods of the trial. This trend is supported by Figure 9, which illustrates the mean heart rate for each treatment condition.

Table 12: Mean difference in the change of heart rate when wearing the CBCS or CBA, compared with wearing the DPCU, during each of three phases of HF trials at HRTA.

	CBCS - DPCU		CBA - DPCU	
	Mean Diff	*p*	Mean Diff	*p*
Patrol	4	0.33	2	0.59
Observation Post	2	0.50	5	0.06
Assault	4	0.48	7	0.08

Note: The table shows that the progression of heart rate was statistically equivalent for each of the garment systems evaluated, during each phase of the trials. For example, wearing the CBA during the assault appeared to increase heart rate by 7 beats$\cdot$min^{-1} more than if the DPCU was worn alone; which tended toward statistical significance.

3.6.2 HF5-HF6, LCBS

Figure 10 illustrates the heart rates during HF5 for individual soldiers. These heart rates were consistent with metabolic, hydration and body temperature data in demonstrating that soldiers were working at high intensities, and that there was substantial individual variation in these relative intensities. The mean relative work intensity for the section was ~60% of estimated V_{O2max}, when averaged across the entire duration of the patrol, where $\%V_{O2max}$ is based on the peak heart rates obtained during the incremental cycle tests to exhaustion.

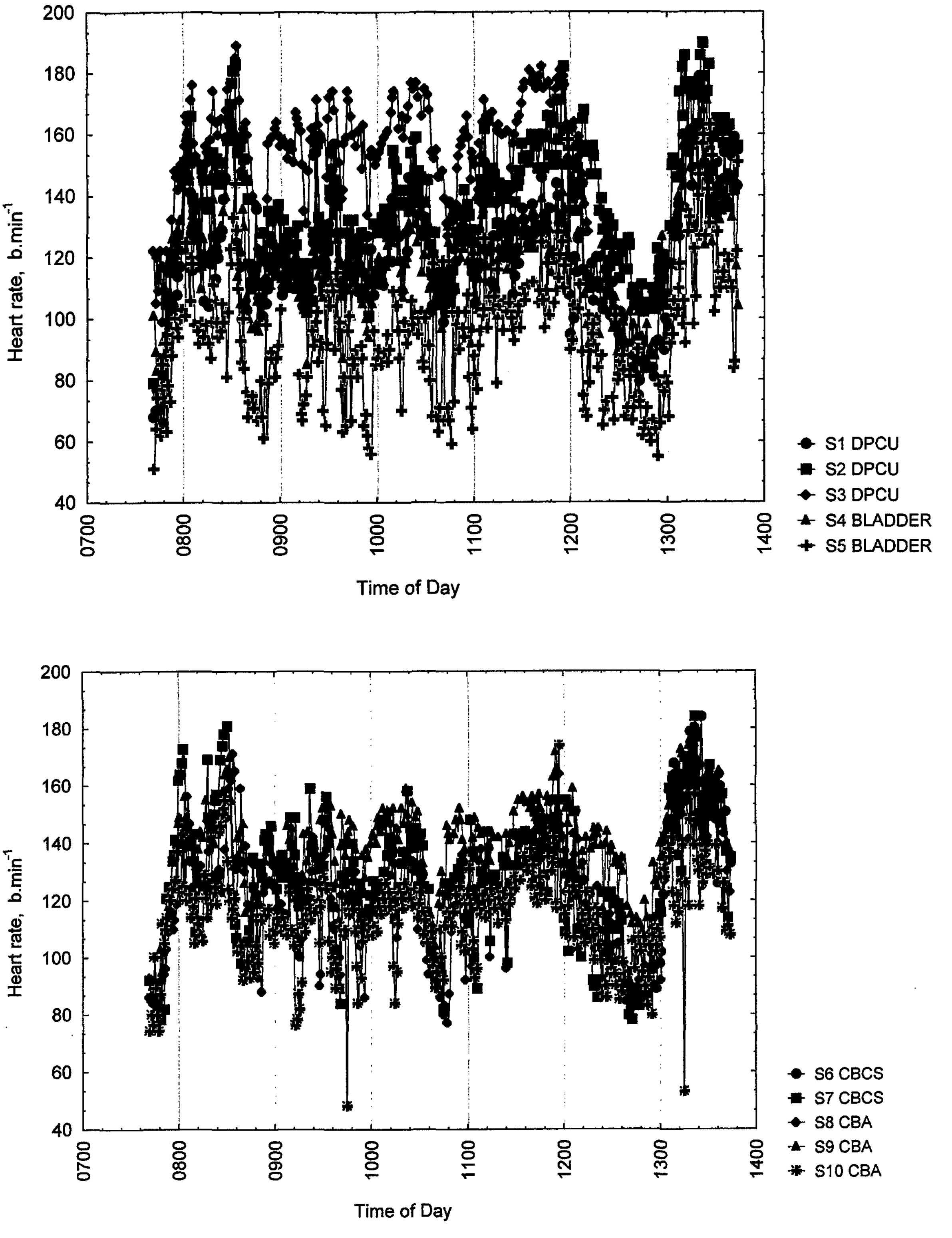


Figure 8: Heart rate for each soldier, as a function of elapsed time, during HF1 at HRTA. Soldiers patrolled until 1205, then remained in an Observation Post until 1300, before engaging in an assault from 1307 until 1330. Note the maintained, high heart rate of Soldier 3, prior to his withdrawal at 1155.

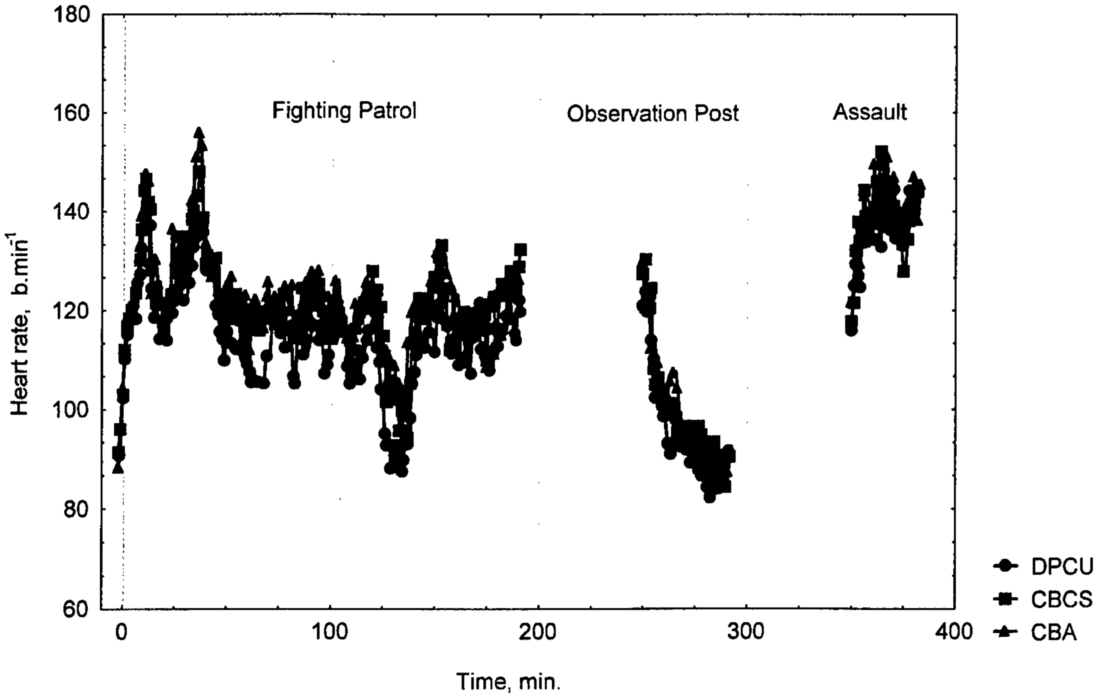


Figure 9: Mean heart rate for each treatment condition, as a function of elapsed time during HF trials at HRTA. The times which denote the onset of observation (250 min) and assault (350 min) periods are arbitrarily defined for the purpose of data illustration. That is, each garment type was worn on different days by different soldiers, and because the durations of patrolling, observation and assault were not identical each day, it is not possible to join the data between these three periods. Note that while the CBCS and CBA appear to have caused mild additional cardiovascular strain during all phases of the trial, this was not statistically significant (Table 12).

In contrast to the methodological success with which body temperature was examined across treatment conditions during the HF5-HF6 experiment at LCBS, it was not possible to similarly examine cardiovascular strain. Heart rate data were entirely absent (n=5) or incomplete (n=1) during HF6 (Appendix 7), thereby preventing a statistical analysis of the effect of wearing the CBA on cardiovascular strain. It is believed that the data were lost because loggers switched out of logging mode due to spurious heart rates arising from signal interference between soldiers, while in transit. This problem was undetected by the DSTO observer, due to his preoccupation with initiating respiratory data logging, and due to the Section Commander beginning the patrol immediately after alighting from the transport.

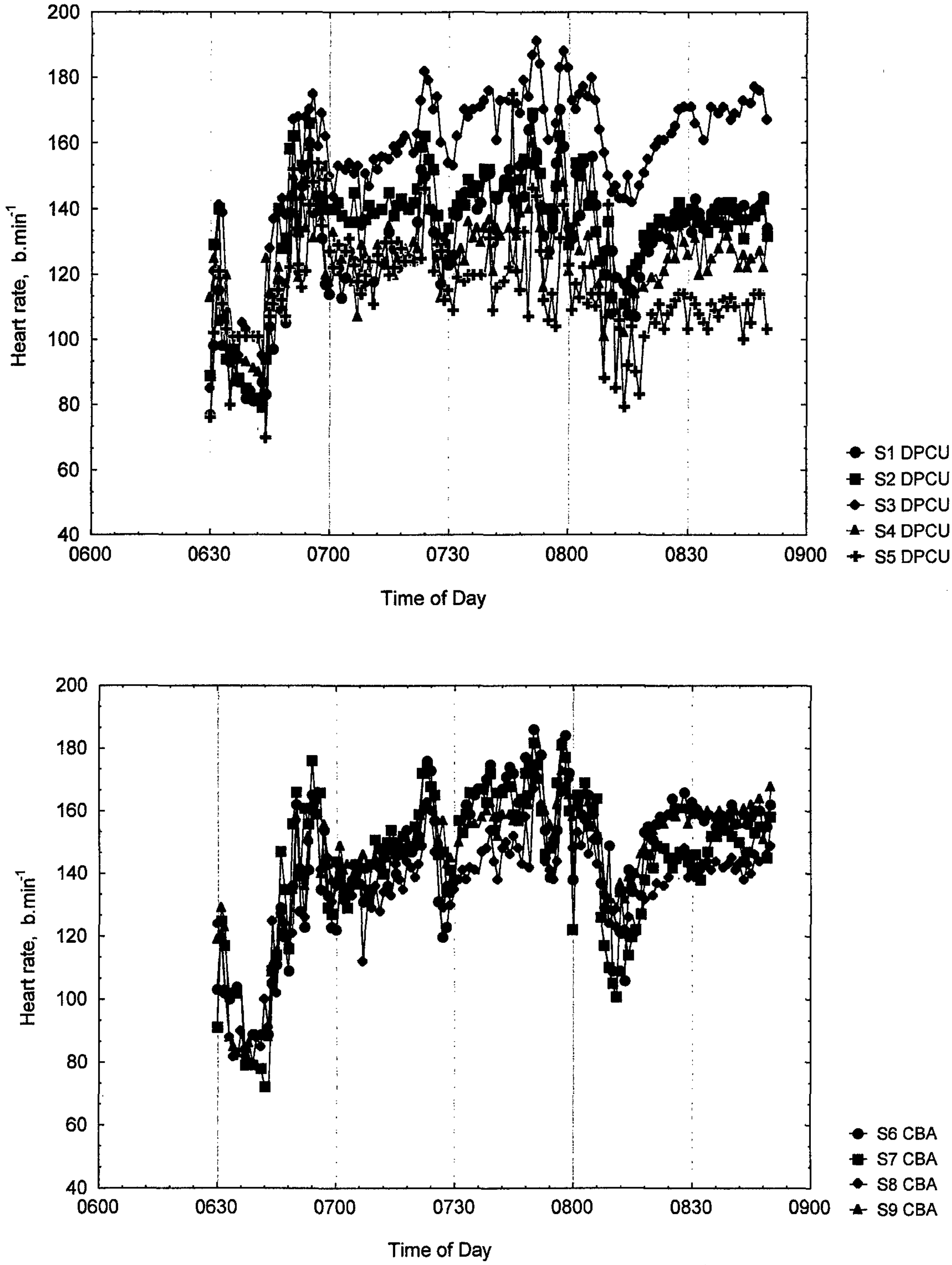


Figure 10: Heart rates of individual soldiers as a function of elapsed time during patrol HF5 at LCBS. Note the progressive cardiovascular strain of soldier 3 (Gunner, who had the lowest measured cardiorespiratory fitness in this section, and who withdrew in HF1), relative to soldier 5 (who had approximately the highest fitness in this section).

3.7 Hydration

The aim was to determine both the practicality of, and the suitability of the present methods to, field measurement of the changes in hydration status associated with treatments in the heat (hot/wet and hot/dry).

3.7.1 HF1-HF4, HRTA

Appendix 8 shows the full data on all soldiers for the activities HF1-HF4. Appendix 9 shows the hydration summaries for each soldier. Table 13 shows the mean (±SD) results obtained for hydration parameters.

The aim of the study design for the activities HF1-HF4 was to replicate conditions (other than treatments) on four successive days to allow statistical analysis of the effects of treatments on hydration status. Unfortunately, the timings and nature of activities were not consistent from day to day, leading to different conditions for each of the activities HF1-HF4. For example, the rate of weight loss was apparently greater for HF1 than for HF2-HF4. This probably relates to the later start time (leading to exposure to higher temperatures and greater solar load) for HF1. Rates of sweating, water intake and urine production were very similar between all four studies.

Table 13: Mean ±SD for rate of water intake, rate of urine production, total sweat rate, non-evaporative sweat rate and evaporative sweat rate for HF1-HF4.

Activity		Rate of Weight Loss ($kg.h^{-1}$)	Rate of Water Intake ($L.h^{-1}$)	Rate Urine Prod ($L.h^{-1}$)	Total Sweat Rate ($L.h^{-1}$)	Non-evap Sweat Rate ($L.h^{-1}$)	Evap Sweat Rate ($L.h^{-1}$)
HF1	Mean	0.37	0.67	0.05	0.99	0.14	0.85
	SD	0.20	0.18	0.03	0.29	0.05	0.29
HF2	Mean	0.24	0.66	0.06	0.92	0.22	0.76
	SD	0.26	0.15	0.05	0.24	0.07	0.21
HF3	Mean	0.22	0.73	0.09	0.93	0.23	0.70
	SD	0.20	0.25	0.07	0.17	0.12	0.10
HF4	Mean	0.26	0.68	0.08	0.97	0.18	0.80
	SD	0.17	0.20	0.08	0.13	0.08	0.16

Sweat rates of approximately 1.0 L per hour were not extreme and were comparable to those previously described for soldiers engaged in patrolling in the heat. Mean urine production of 50 - 90 mL per hour was quite low, but was still comfortably above the generally recognised minimum obligatory rate of about 15 mL per hour, indicating that marked hypohydration (lower-than-normal total body water volume) had not occurred. However, the mean result conceals a wide variation in urine production. As indicated by the high standard deviations (approximately equal to the means), urine production varied greatly between soldiers. One soldier (Soldier 5) had consistently higher water intake and urine production than all other soldiers. He also managed to *gain* weight during three of the four HF studies (Appendix 9). One soldier (Soldier 9) had consistently high weight loss. The implication of this was that he was becoming hypohydrated at a considerable rate.

The activities of HF1-HF4 were conducted over relatively short time periods (~5 hours), so marked hypohydration was not observed. Whether or not the high rate of dehydration of Soldier 9 would have continued had the patrolling phase been long-term is not known. It is known that many soldiers do not drink enough water to maintain euhydration (normal total body water volume) in the heat. This phenomenon is termed 'voluntary dehydration', although it would perhaps be better named 'involuntary dehydration', because the soldier is usually not aware of the level of hypohydration that is occurring. It may be that the temperature of the water, the lack of flavouring and the method of delivery (water bottles for about 50% of the time) adversely affected water intake.

3.7.2 HF5 & HF6, LCBS

Appendix 8 shows the raw data obtained for hydration status of the soldiers during HF5 and HF6. Appendix 9 shows the hydration summaries for each soldier. Table 14 shows the mean value ± SD for hydration parameters.

Table 14: Mean ±SD for rate of water intake, rate of urine production, total sweat rate, non-evaporative sweat rate and evaporative sweat rate for HF5&HF6.

Activity		**Rate of Weight Loss ($kg.h^{-1}$)**	**Rate of Water Intake ($L.h^{-1}$)**	**Rate of Urine Prod ($L.h^{-1}$)**	**Total Sweat Rate ($L.h^{-1}$)**	**Non-evap Sweat Rate ($L.h^{-1}$)**	**Evap Sweat Rate ($L.h^{-1}$)**
HF5	Mean	0.57	0.84	0.20	1.40	0.88	0.52
	SD	0.39	0.40	0.18	0.36	0.30	0.33
HF6	Mean	0.63	1.14	0.12	1.64	1.04	0.70
	SD	0.17	0.47	0.13	0.59	0.31	0.38

Rate of water intake, total sweat rate and non-evaporative sweat rate were all higher for HF5 and HF6 than for HF1-HF4. Conversely, evaporative sweat rate was lower for HF5 and HF6. These results are consistent with the climatic differences between HRTA and LCBS. There was a higher thermal stress on soldiers at LCBS due to a similar heat load as for HRTA but with a higher humidity; therefore soldiers sweated at a greater rate. However, the high humidity also led to a lower evaporation rate at LCBS, meaning that much of the sweat was wasted (lost to the body as liquid water, and hence not aiding in heat dissipation).

The results indicate that working hard in the hot/wet environment of LCBS led to greater requirement for water than occurred in the hot/dry conditions at HRTA.

3.7.3 Comparison of DPCU with CBA

Appendix 8 shows the data for the results on hydration status of soldiers obtaining their water from water bottles while wearing either DPCU or CBA during the HF1-HF4 phase. Table 15 shows the summary results (mean value ± SD) of hydration status for DPCU versus CBA. Appendix 8 shows the raw data for hydration status of soldiers wearing DPCU or CBA in HF5 and HF6. Table 16 shows the hydration summary for DPCU versus CBA for HF5 and HF6.

Overall, there was an increased requirement for water associated with the wearing of CBA. This is to be expected because CBA provides an additional layer of clothing above the DPCU and adds about 2 kg to the weight carried. However, there were noticeable differences between the two groups of activities, with rates of weight change, water intake and sweating much higher at LCBS (HF5&HF6) than at HRTA (HF1-HF4). This is indicative of higher heat stress at LCBS and is to be expected, because hot/wet environments do not allow efficient cooling by sweating, while hot/dry conditions are more amenable to such cooling.

Table 15: Effects on hydration status of wearing DPCU alone compared with DPCU plus CBA for HF1-HF4.

Uniform		Rate of Weight Change ($kg.h^{-1}$)	Rate of Water Intake ($L.h^{-1}$)	Sweat Rate ($L.h^{-1}$)	Non-Evap Sweat Rate ($L.h^{-1}$)	Evap Sweat Rate ($L.h^{-1}$)	Rate of Urine Production ($L.h^{-1}$)	Final Urine Sodium ($mmol.L^{-1}$)	Final Urine SG
DPCU	Mean	0.22	0.63	0.84	0.15	0.69	0.08	38.88	1.023
	SD	0.27	0.20	0.16	0.04	0.18	0.05	47.28	0.008
CBA	Mean	0.31	0.75	1.04	0.19	0.85	0.07	19.33	1.029
	SD	0.26	0.31	0.30	0.09	0.30	0.09	21.20	0.003
Difference (CBA-DPCU)	Mean	0.09	0.12	0.20	0.04	0.16	-0.01	-19.55	0.004
Probability		**0.04**	0.16	**0.03**	0.10	**0.05**	0.26	0.18	0.07

Probabilities of 0.05 or below (bolded) show statistically significant difference between treatments.

Table 16: Effects on hydration status of wearing DPCU alone or DPCU plus CBA for HF5&HF6

Uniform		Rate of Weight Change ($kg.h^{-1}$)	Rate of Water Intake ($L.h^{-1}$)	Total Sweat Rate ($L.h^{-1}$)	Non-Evap Sweat Rate ($L.h^{-1}$)	Evap Sweat Rate ($L.h^{-1}$)	Rate of Urine Production ($L.h^{-1}$)
DPCU	Mean	0.67	0.85	1.33	0.81	0.53	0.19
	SD	0.42	0.41	0.35	0.21	0.33	0.19
CBA	Mean	0.72	1.12	1.71	1.11	0.69	0.13
	SD	0.37	0.47	0.55	0.32	0.38	0.13
Difference	Mean	0.05	0.27	0.38	0.30	0.16	-0.06
Probability		0.31	0.07	**0.02**	**0.01**	0.14	0.22

Probabilities of 0.05 or below (bolded) show statistically significant difference between treatments.

3.7.4 Water Intake

There is a potential problem to be overcome. Soldiers were weighed and then waited for up to 100 minutes before the patrol began. During that time, most soldiers drank water. A second weighing, in full patrol order, immediately before the departure, is needed to determine the weight change, if any.

3.7.5 Weight Loss

There was a statistically-significantly greater weight loss when wearing CBA compared to DPCU in HF1-HF4, but only a very slight increase (not statistically-significant) in weight loss for CBA relative to DPCU in HF5 and HF6.

It should also be noted that the measurement of soldiers in patrol order proved to be of no use in the determination of hydration status in this study. It is concluded that, unless a second weighing is conducted in patrol order as an indication of change in hydration status following the initial weighing in future studies, only measurements of semi-nude and uniformed weights are necessary, saving time for both scientists and soldiers[8].

3.7.6 Sweat Rate

The following effects on sweat rate were found:

(i) Total sweat rate was significantly greater in both groups of studies HF5 and HF6 for CBA than for DPCU;
(ii) Non-evaporative sweat rate was significantly greater for CBA than for DPCU only in HF5 and HF6; and
(iii) Evaporative sweat rate was significantly greater for CBA only in HF1-HF4.

The method of estimating overall sweat rate by weight difference was found to be easy to perform in the field and appears to be sensitive to treatment effects. Certainly, statistically-significant treatment effects were found in this study.

As mentioned in the Methods section, there is some doubt about the accuracy of measurement of non-evaporative and evaporative sweat. This is because non-evaporative sweat was estimated as the increase in weight of the soldier's uniform from start to finish of the activity. However some of the sweat produced, especially at LCBS, was probably lost through dripping.

3.7.7 Other Hydration Parameters

No other statistically significant relationships were found, although there was a trend to greater final specific gravity of urine when wearing CBA at HRTA. These different treatment effects between HF1-H4 and HF5 and HF6 may be due to differences in the climatic conditions experienced at LCBS compared to HRTA, as discussed in the next sub-section.

[8] This assumes that for each configuration being examined (ie. basic and enhanced), the amount of water absorbed by non-clothing items (eg. pouches and webbing) is only negligible, or is at least consistent between configurations.

3.7.8 Climatic Effects

The climate was hot/wet at LCBS and (at least relative to LCBS) hot/dry at HRTA. As mentioned above, at HRTA the evaporative sweat rate while wearing CBA was *higher* in the drier heat, implying that the CBA allows evaporative cooling of the soldier to occur, presumably via the micro channels on the inner surface of the CBA. This is supported by the finding that non-evaporative sweat rate was virtually identical between the treatments at HRTA, implying that the CBA/DPCU ensemble did not absorb significantly more water than DPCU alone. Therefore, in hot/dry climates, wearing the CBA over the DPCU would not be expected to add considerably to the heat strain of dismounted soldiers engaged in normal operations.

Similarly, at LCBS all the trends were towards greater water requirements when CBA was worn than with DPCU alone. However, in contrast to HRTA, non-evaporative sweat rate was significantly higher for CBA than for DPCU alone. This implies that in hot/wet conditions, the extra layer of clothing led to much greater absorption and retention of sweat, reducing the capacity of the soldiers to lose heat by evaporative cooling. In contrast to the hot/dry scenario, in hot/wet conditions dismounted soldiers might expect to experience greater heat strain when wearing CBA than when wearing DPCU alone.

3.7.9 Comparison of DPCU with CBCS

Appendix 8 shows the complete hydration results for hydration status of soldiers wearing DPCU compared with CBCS for HF1-HF4. Table 17 shows the hydration summary for DPCU versus CBCS. The rate of weight change and total sweat rate were greater for CBCS than for DPCU, implying that CBCS may have led to increased rate of hypohydration. However, these differences were not statistically significant and so can only be said to indicate a possible trend. There was no noticeable difference in final urine sodium or SG between treatments. The only significant difference was the non-evaporative sweat rate (p=0.001). From this it appears that the CBCS absorbed and retained more water than did the DPCU. However, in the relatively dry heat of HRTA, the absolute amount of water retained by either uniform was not great. Evaporative sweat rate was identical between treatments, suggesting that CBCS did not significantly reduce the rate of heat dissipation due to sweating, rather it may simply have led to a requirement to sweat more to achieve the same level of heat loss. On the basis of these results it is concluded that wearing CBCS may add only slightly to water requirements of soldiers engaged in operations in hot/dry climates. This is supported by anecdotal evidence from the soldiers themselves who stated that they actually felt cooler when standing in a slight breeze in the shade while wearing CBCS than when wearing DPCU.

Table 17: Effects on hydration status of wearing DPCU or CBCS

Uniform		Rate of Weight Change ($kg.h^{-1}$)	Rate of Water Intake ($L.h^{-1}$)	Total Sweat Rate ($L.h^{-1}$)	Non-Evap Sweat Rate ($L.h^{-1}$)	Evap Sweat Rate ($L.h^{-1}$)	Rate of Urine Production ($L.h^{-1}$)	Final Urine Sodium ($mmol.L^{-1}$)	Final Urine SG
DPCU	Mean	1.11	0.63	0.84	0.15	0.68	0.08	38.88	1.023
	SD	1.36	0.20	0.16	0.04	0.18	0.05	47.28	0.008
CBCS	Mean	1.46	0.66	0.93	0.24	0.68	0.09	51.29	1.022
	SD	0.95	0.14	0.20	0.08	0.17	0.09	48.70	0.008
Difference	Mean	0.36	0.03	0.10	0.09	0.00	0.01	6.86	0.00
	SD	1.23	0.18	0.22	0.05	0.23	0.05	68.33	0.01
Probability		0.22	0.34	0.13	**0.001**	0.50	0.27	0.40	0.50

4. Conclusions

This study was conducted on a small sample of soldiers (*N*=10). The principle aim of the study was to investigate analytical methodology. It is not considered appropriate that definitive conclusions be drawn on the physiological effects of wearing CBA and CBCS systems. Nevertheless, based on the results of this study the following trends are noted:

4.1 Methodological

1. The present methodology revealed the following inadequacies, which must be avoided if the physiological impacts of soldier combat system enhancements are to be quantified.

   a) There were variations in experimental conditions between trials (days). These variations, which seriously affected the validity of comparisons between configurations, were:
      i) Time of Day;
      ii) Duration of patrol;
      iii) Route differences (trend to shorten, and increase speed with repetition of operation);
      iv) Environmental conditions.

   b) Measurement of body temperatures was unreliable:
      i) The Squirrel temperature loggers were not sufficiently robust. These have been returned to the supplier for service, and if again prove inadequate, will be replaced by loggers which are robust, but have less recording flexibility.
      ii) Skin thermistors became dislodged during early trials, though the problem was solved by modifying the method of attachment to the skin.
      iii) Rectal thermistors frequently became dislodged, particularly during hill climbing and assaults. Despite efforts to minimise this problem, it remains unsolved.

   c) Studies of the hydration status of soldiers can be conducted using relatively straightforward methods in the heat during simulated operations. Water intake, weight loss, urine production, and total sweat rate were determined simply by weight differences. This method is considered to be entirely accurate, simple and reliable in the field, provided that the scales used are properly calibrated, have high resolution (at least 50 g) and mounted on a flat surface.

d) Interference of telemetrised data between soldiers (heart rate). While this problem was often minor, it also resulted in almost complete loss of data from one trial (due to the loggers switching out of record mode after sustained interference).

4.2 Stress-Related

1. The robustness of the Metamax used for V_{O2} measurements was demonstrated.

2. Using the ergospirometer in selected field situations provides real time measurements of oxygen consumption, and therefore of metabolic stress associated with different activities.

3. Applicability of Metamax is limited to day time measurement only as the face mask can interfere with weapon sighting, particularly in the dark.

4. Metabolic rates, if used in conjunction with other sources of stress (from clothing and environment), may be used as a general guide for planning of work-rest schedules.

5. Field evaluations of physiological strain associated with given activities and/or soldier enhancements, must include accurate measures of environmental thermal stress. Whilst the WBGT currently provides such information, the validity of this measure requires further scrutiny.

6. The higher stress imposed by the reconnaissance patrol at LCBS was of suitable intensity to reveal differences in physiological burden associated with wearing different combat uniforms in the tropics. An activity such as the assault at HRTA would be unlikely to reveal such differences, because the heat stress is so high that it is totally uncompensable.

4.3 Strain-Related

1. Core temperature, mean skin temperature and heart rate are appropriate measures for evaluating the physiological burden of soldier combat system enhancements.

2. Current techniques for measuring mean skin temperature and heart rates are adequate.

3. The measurement of core temperature using rectal thermistors has significant limitations, especially during vigorous activities, such as hill climbing and crawling.

4. An estimate can be made of sweating efficiency (ratio of evaporated to total sweat) by weight differences, but the validity of this procedure is undetermined. Examination of weight loss, relative to changes in heat content, as determined from core and skin temperatures, would allow qualitative assessment of the influence of soldier enhancements on sweating efficiency.

5. For field studies of hydration, there may be no need to analyse urine for sodium; specific gravity is more easily measured and appears to provide adequate information on hydration status.

4.4 Physiological Impact of Enhancements

The use of CBA on operations in hot/dry climates may increase total sweat rate (and therefore water requirements) but may not add significantly to heat strain of soldiers;

1. Wearing CBA during operations in hot/wet environments may increase water requirements and heat strain in soldiers;

2. Wearing CBCS on operations in hot/dry climates may add slightly to water requirements without increasing heat strain;

3. The effects of wearing CBCS on operations in hot/wet environments need to be investigated.

5. Recommendations

The following recommendations are made on the basis of present methodology:

5.1 Experimental Design and Procedures

1. Because of the nature of many physiological indices of strain, it is imperative that experimental conditions are replicated as fully as possible between treatments. This requires:

   a) More use of laboratory trials, where appropriate, to evaluate the physiological implications of soldier combat system enhancements. The laboratory trials would normally occur prior to, or possibly in place of, field trials;

   b) Balanced order, within-subjects experimental designs where possible. Although such designs are more difficult to administer, and increase the variability in recorded dependent variables, they are usually necessary because they minimise the impact of non-quantifiable, confounding factors (eg. carry-over effects, and day-to-day differences in patterns or levels of environmental or metabolic stress);

   c) A period of standardised activity (probably 5-10 minutes, quietly seated) before each trial, to ensure reliability of baseline data for each treatment condition;

   d) It is of paramount importance that scientists and commanders agree on the scientific protocol to be followed in all future studies in Land125. This protocol should not be varied without the agreement of both parties. In particular, there should be:
      i) Prior agreement on, and commitment to, key experimental parameters (time of day, duration, route and speed of patrol) by both organisations;
      ii) Discussion between DSTO and Section Commander during the course of the experiment;
      iii) Increasing the role of the SME within trials, to maximise standardisation of the task;
      iv) Inclusion of a DSTO observer within trials, to minimise loss of data and to document relevant experimental details;
      v) Improved health screening prior to the onset of data collection;
      vi) Specific, verbalised instruction to the soldiers, including emphasis of what is being investigated, and therefore the ways in which they can prevent undue loss of data (eg. prohibit swapping ammunition or

urinating against trees). The briefing should involve the provision to all soldiers of a written summary of their required actions.

e) Limiting the scope of the experiment to as few comparisons, or levels, as possible (eg. a comparison of basic and enhanced modes).

2. The following modifications should be considered when experiments are expected to involve data collection problems (eg. uncertainties in the level stress imposed by environment or task):

a) Running a pilot trial which **fully** replicates one experimental trial. This will allow fine-tuning of the protocol (by experimenters and soldiers), and also provides backup or test:retest reliability data. In view of the data logging and/or protocol problems during field activities, the pilot trial is considered a valuable avenue for obtaining backup data;

b) Where data loss is expected to be appreciable, facility should be made for repeat experiments to reacquire lost data.

5.2 Strain-Related Measurements

1. Core temperature:

a) Hasten development of alternative indices:
   i) Determine relative efficacies of the infrared tympanic and insulated skin temperature monitors which are currently at the prototype stage, and which require experimental verification of their ability to yield core temperature;
   ii) Compare the efficacy of the above techniques with a recently acquired, gastrointestinal radio pill for core temperature measurement.

b) Use the DSTO observer to conduct regular thermometry checks, including:
   i) Ad hoc checks during routine operations,
   ii) Immediately following vigorous events (e.g. attacks).

c) Undertake testing of loggers to determine their true field-related capabilities.

2. Heart rate:

a) Investigate possibilities of hard-wired output (from detector to logger) or individualised frequency in the telemetry. If neither approach is possible, then minimise data loss by:

i) Minimise instances of close (<2 m) proximity of soldiers to each other, and
ii) Use the DSTO observer to check logging status frequently.

3. Oxygen Consumption:

a) Where the activity is tightly defined and controlled, respiratory data can be used to estimate the metabolic stress of an activity and its component parts. However, it should be remembered that there is considerable error involved with determination of metabolic rate from respiratory measures, and it will therefore usually be of dubious value in detecting (subtle) differences in metabolic rate arising from soldier combat system enhancements.

b) Where the activity is relatively uncontrolled, there will usually be much larger differences in metabolic rate between trials, and therefore the measurement of metabolic rate is a valuable measure of differences in stress between trials or systems.

5.3 Data Analysis

1. As a first step, there should be at least informal analyses (eg. visual inspection) of the initial, or basal, levels of measured variables. This is especially important if dependent variables are to be analysed using change scores (across a defined task or period). Circumstances which might involve dependent variables being different between treatment groups, prior to onset of data collection, include:

a) Enhancements which involve different clothing insulation or weight to be carried, will affect variables such as mean skin temperature or heart rate (e.g. see Figure 7);

b) Carry-over effects, such as residual hyperthermia, hypohydration, or task learning, have multiple affects;

c) Different soldiers being used for each treatment group.

2. The effects of soldier combat system enhancements on indices of physiological strain can be quantified using integration (time averaging) across the entire task, or change scores between selected events (e.g. onset and completion of task). The following points should be noted when considering how to analyse each dependent variable:

a) Time averaging:

i) Can be less suitable if variables have frequent periods of data loss (e.g. heart rate);
ii) Is suitable for variables which change rapidly or are sensitive to factors which are not constant and are outside experimental control. Examples of such influences include (i) posture and arousal on heart rate; (ii) speed, movement pattern or terrain on respiration; and (iii) posture and cloud or vegetation cover on mean skin temperature.

b) Change scores:
i) The periods used to obtain initial (pre-task) and final (task completion) median or mean data must be wholly within, and representative of, their wider periods. For example, since heart rate and certain respiratory variables are posture and arousal dependent, then care must be taken to avoid sampling data from periods which are influenced by the preceding activity.
ii) Must be used in conjunction with the absolute values.

c) Absolute values:
i) Often not suitable for evaluating differences in strain imposed by different treatment groups, but;
ii) Essential for revealing actual levels of physiological burden experienced, and therefore;
iii) Should be used in conjunction with either time averaging or change scores.

5.4 Logistical

1. Because physiological equipment must be cleaned (for skin surface monitoring) or deep disinfected (for core temperature monitoring), there are hygiene-related issues in selecting the physical location of base areas:

a) A good supply of clean water;

b) Access to a truck-mounted portable medical facility (as currently held by ADF);

c) Opportunity to create at least three partitioned areas, preferably with suitable flooring (eg. concrete);

d) Hygiene standards for collection of bodily fluids (eg. urine, saliva and blood) in the field;

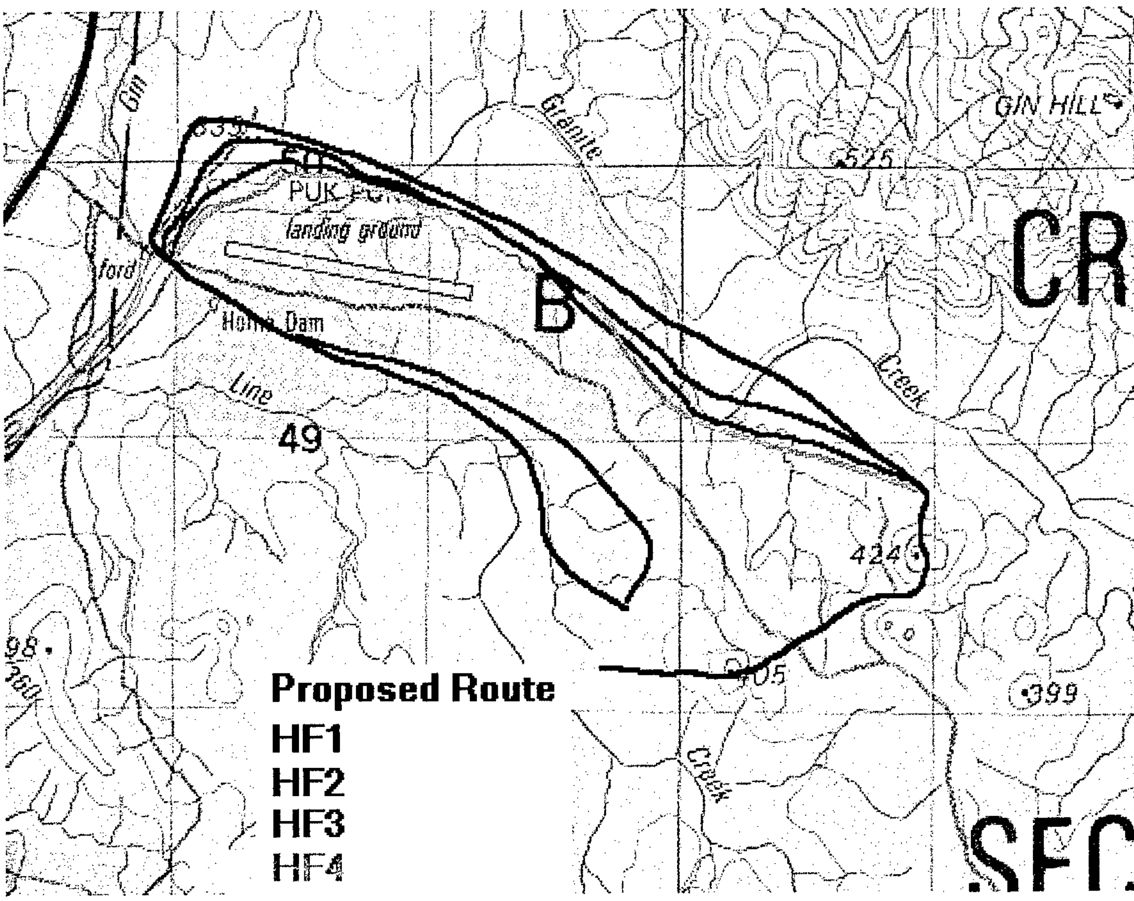
e) Adequate lighting (for soldier preparation or cleaning equipment at night).

2. If the collective decision is that experiments begin at or near sunrise for each trial, which requires an 04:00-05:00 start for preparation of soldiers, then sleeping arrangements must be such that the soldier preparation can proceed without affecting other DSTO or Army personnel.

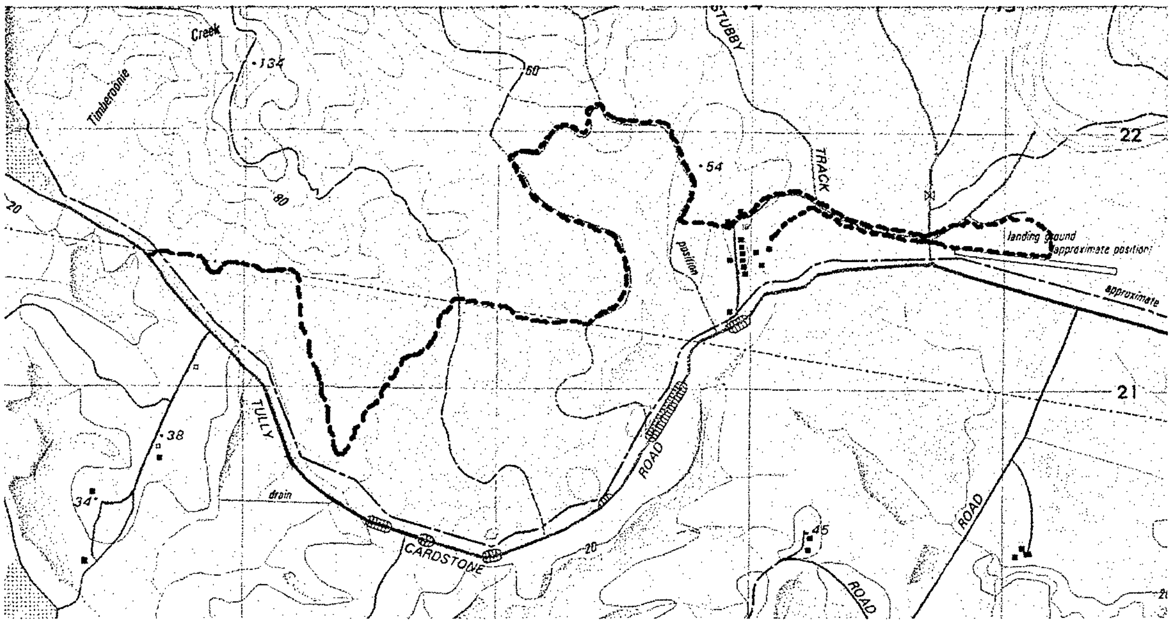
6. Acknowledgments

The professional attitude of the soldiers of C Company, 1RAR and their good-humoured tolerance of very trying conditions is gratefully acknowledged. So too is the assistance (and, for one activity) the participation, of Major Damian Burton, Company Commander, C Company, 1RAR. The assistance of Dr Melissa Crowe of James Cook University in conducting fitness testing and urine analysis is also gratefully acknowledged. The assistance of Mr Bernie Gray for general organisation of the human factors soldiers, equipment and transportation and Mr Peter Sanders in computer support is gratefully acknowledged. Finally, the assistance of DTRIALS and DGLD is acknowledged. Their success rate in 'herding the cats' is regarded as having been instrumental in allowing the studies to be successfully completed.

Appendix 1: Route Map for HF1-HF4 Experiments at HRTA

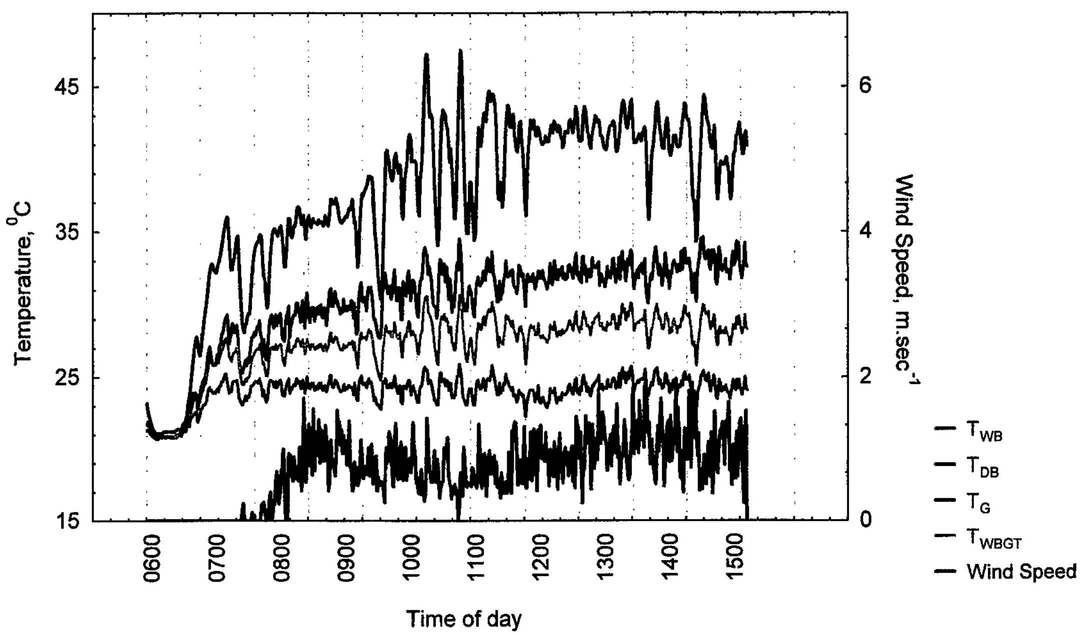


Appendix 2: Route Map for HF5-HF6 Experiments at LCBS Tully

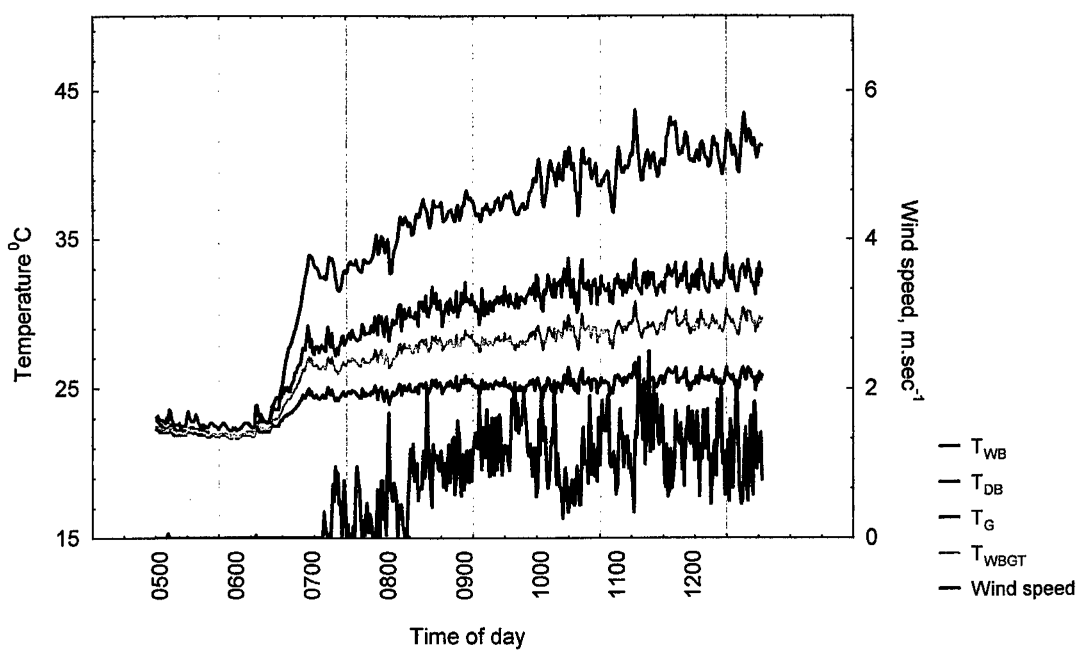


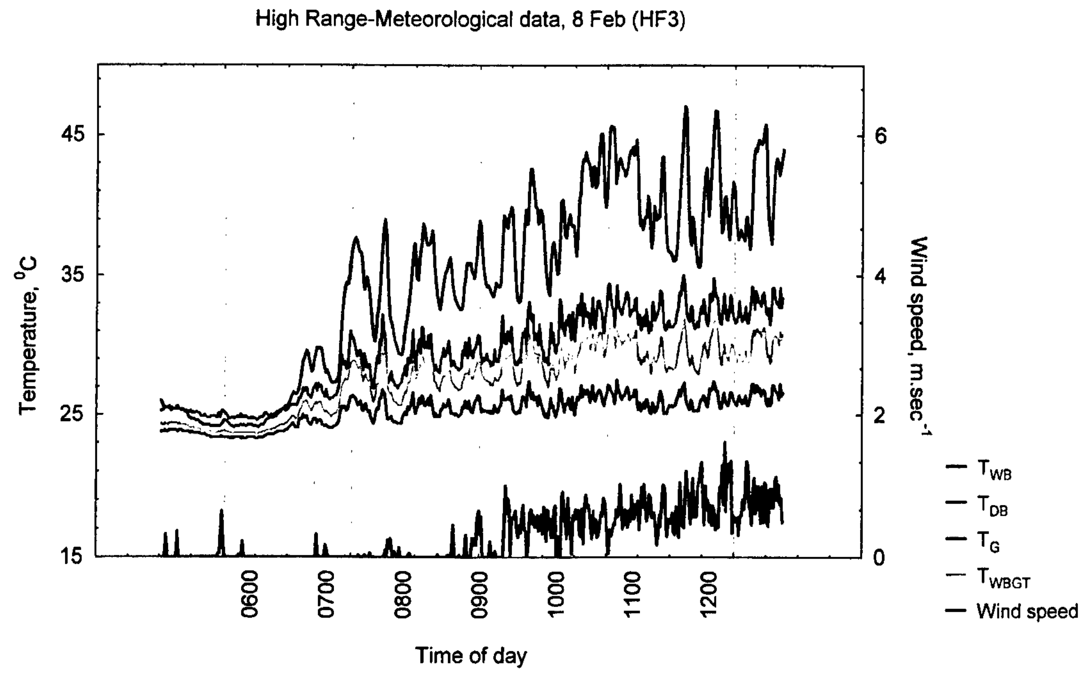
Appendix 3

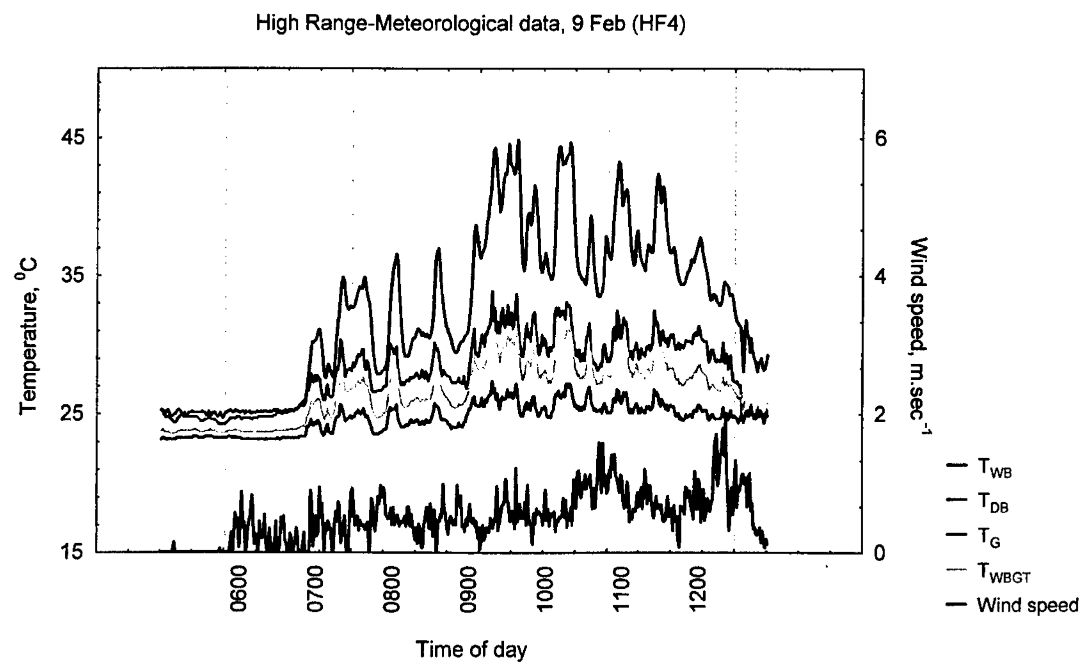
High Range-Meterological data, 6 Feb (HF1)

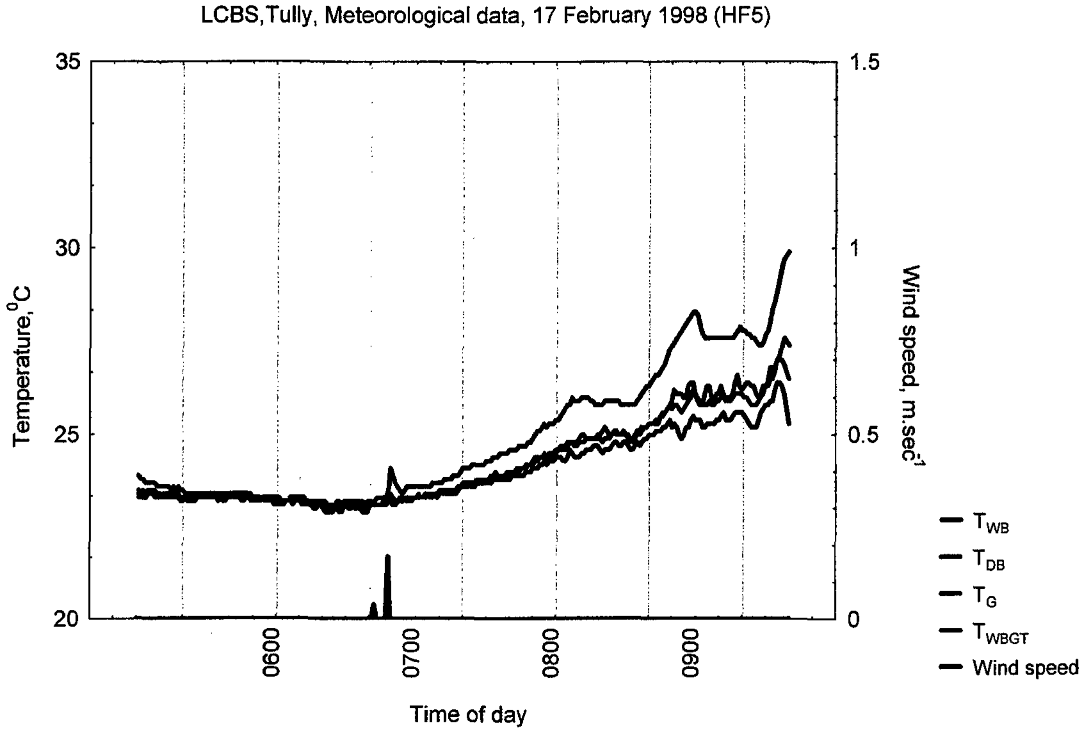


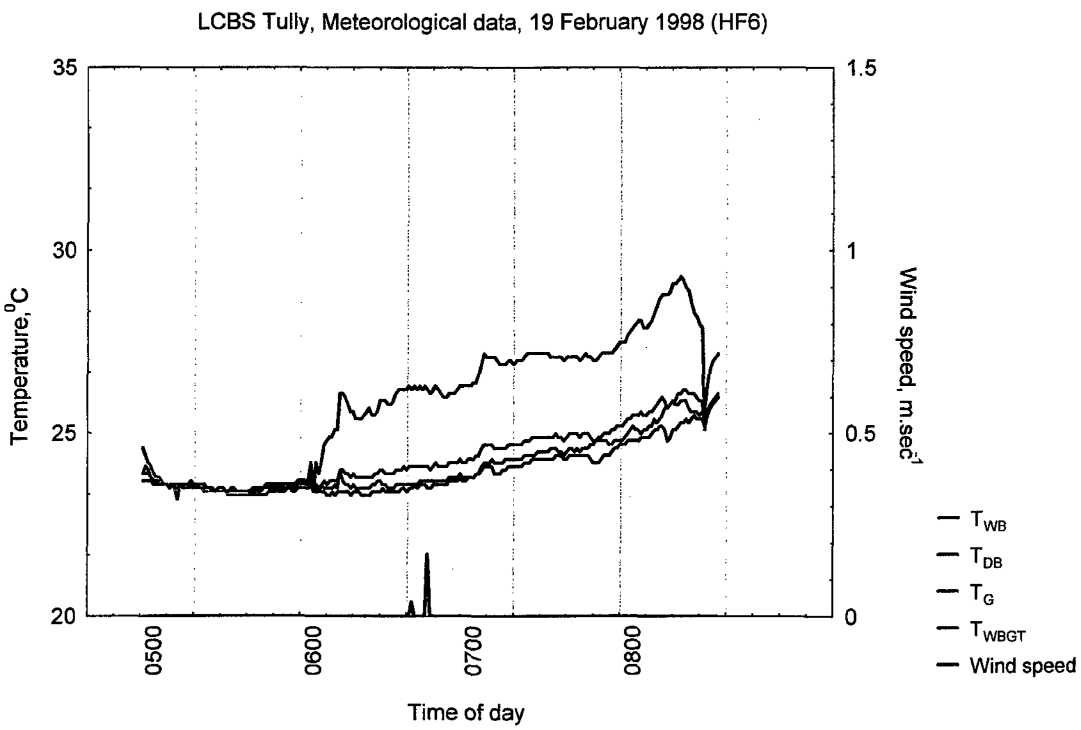
High Range-Meteorological data, 7 Feb (HF2)



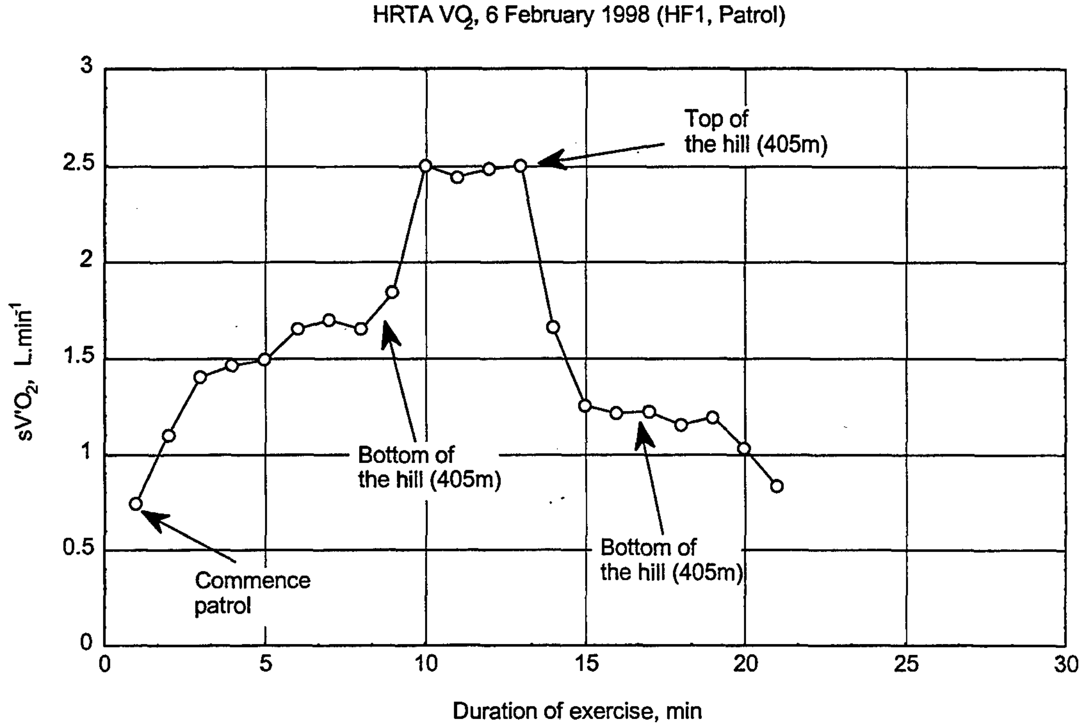

High Range-Meteorological data, 8 Feb (HF3)
Temperature, °C
45
35
25
15
Wind speed, m.sec-1
6
4
2
0
0600
0700
0800
0900
1000
1100
1200
Time of day
TWB
TDB
TG
TWBGT
Wind speed

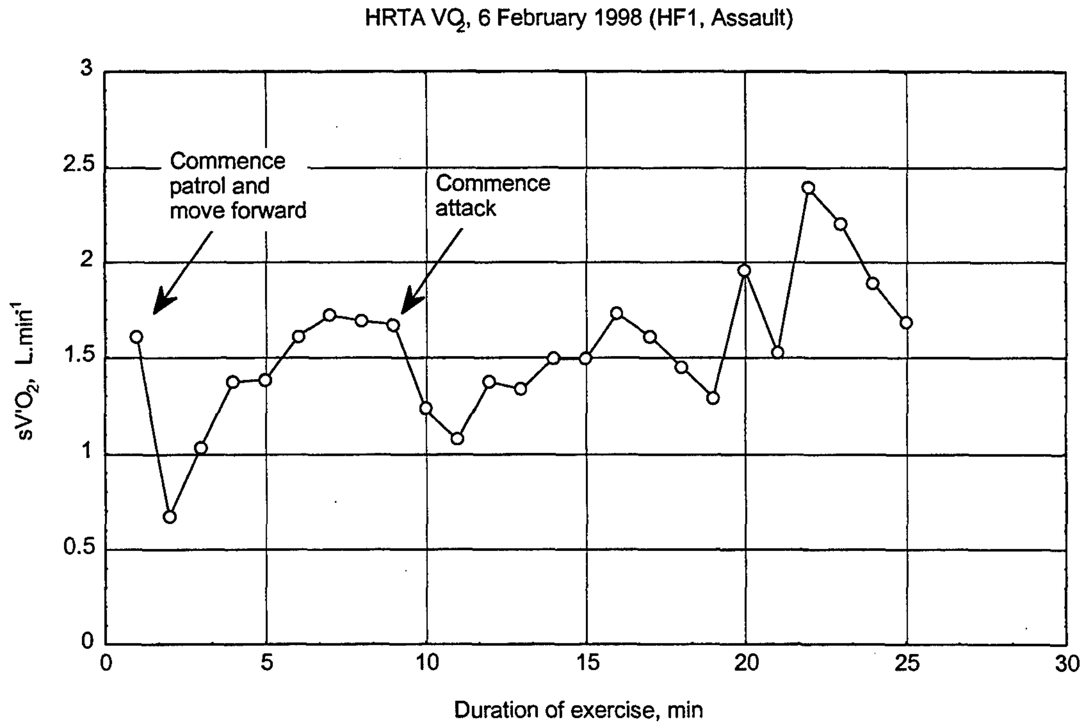

High Range-Meteorological data, 9 Feb (HF4)
Temperature, °C
45
35
25
15
Wind speed, m.sec-1
6
4
2
0
0600
0700
0800
0900
1000
1100
1200
Time of day
TWB
TDB
TG
TWBGT
Wind speed

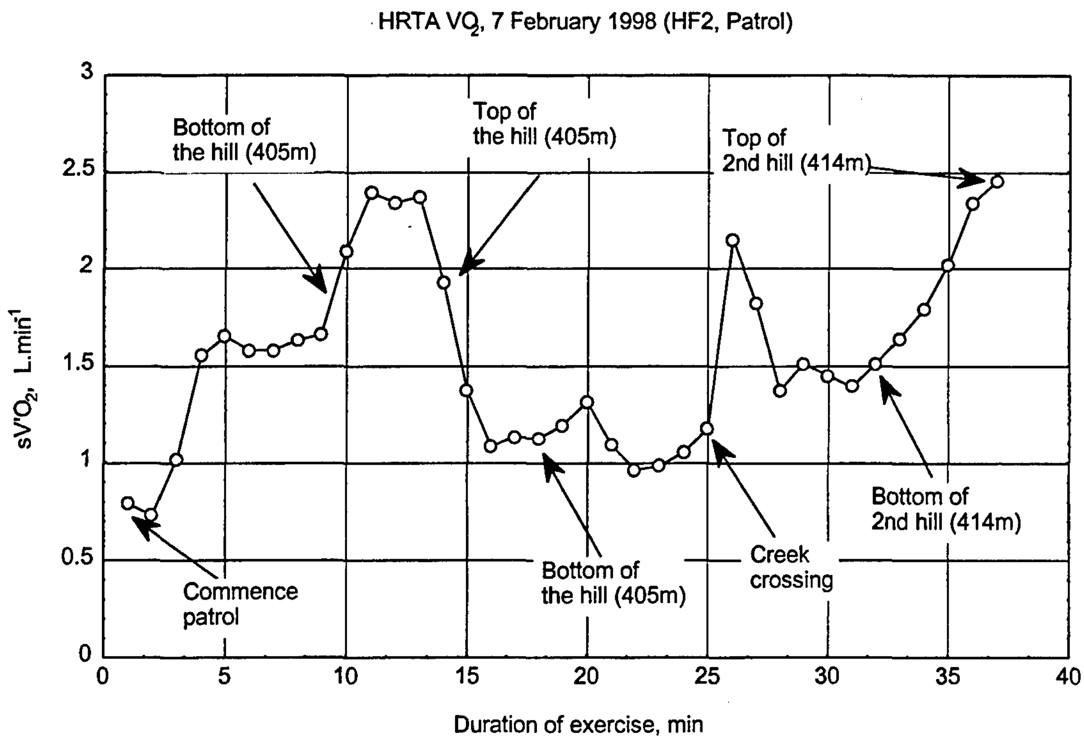

LCBS,Tully, Meteorological data, 17 February 1998 (HF5)
35
30
25
20
Temperature, ^{0}C
1.5
1
0.5
0
Wind speed, m.sec^{-1}
0600
0700
0800
0900
Time of day
T_{WB}
T_{DB}
T_G
T_{WBGT}
Wind speed

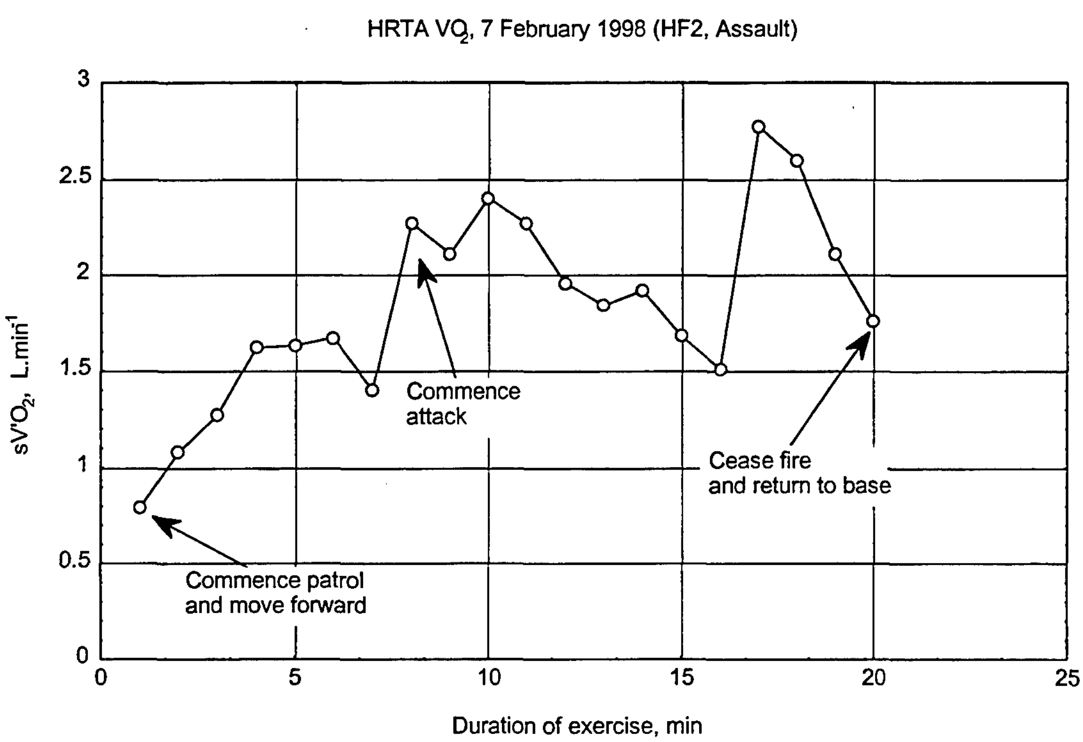

LCBS Tully, Meteorological data, 19 February 1998 (HF6)
35
30
25
20
Temperature, ^{0}C
1.5
1
0.5
0
Wind speed, m.sec^{-1}
0500
0600
0700
0800
Time of day
T_{WB}
T_{DB}
T_G
T_{WBGT}
Wind speed

Appendix 4: Endogenous thermal stress: Oxygen consumption

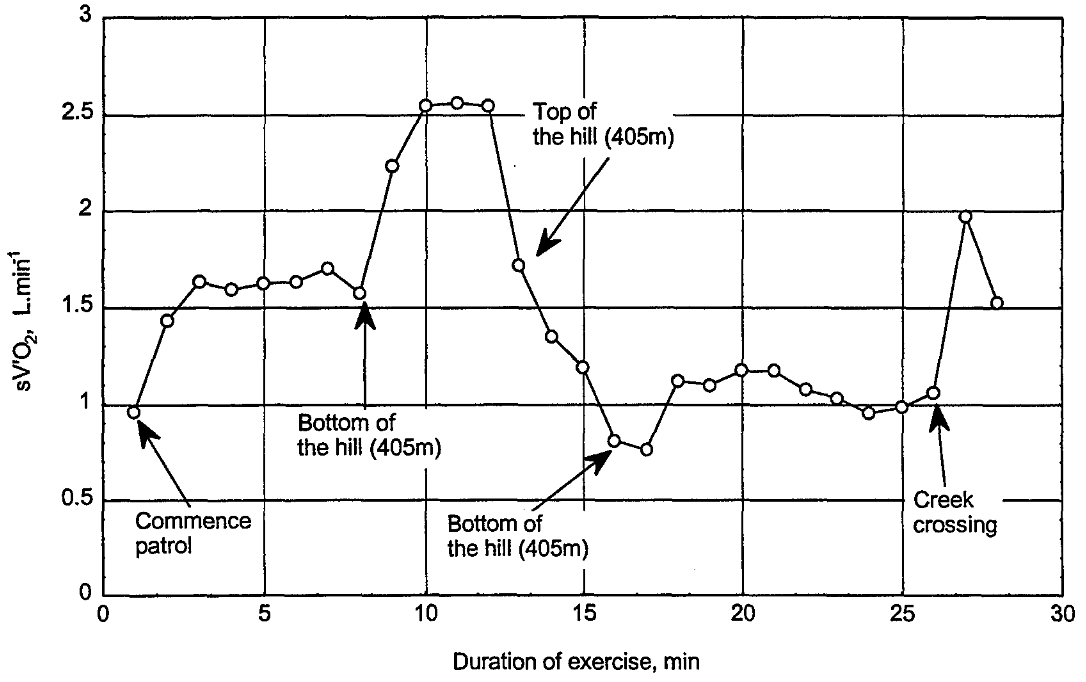




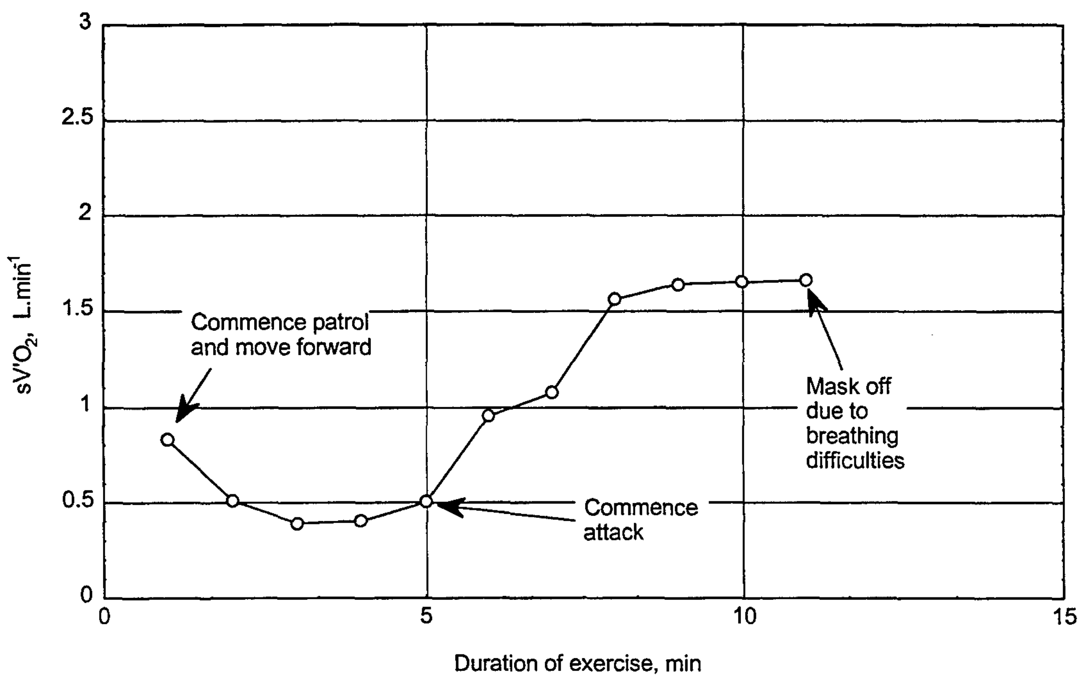

HRTA VO2, 7 February 1998 (HF2, Patrol)
Bottom of
the hill (405m)
Top of
the hill (405m)
Top of
2nd hill (414m)
Commence
patrol
Bottom of
the hill (405m)
Creek
crossing
Bottom of
2nd hill (414m)
sV'O2, L.min-1
Duration of exercise, min
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25
30
35
40


HRTA VO2, 7 February 1998 (HF2, Assault)
Commence
attack
Commence patrol
and move forward
Cease fire
and return to base
sV'O2, L.min-1
Duration of exercise, min
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25

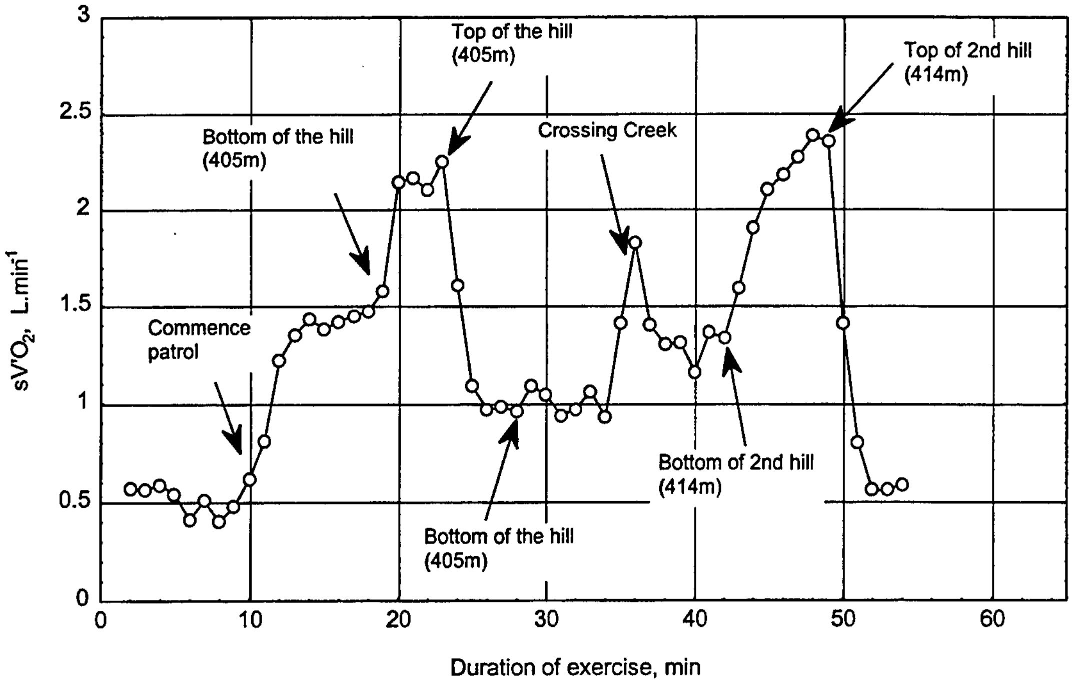
HRTA VO2, 8 February 1998 (HF3, Patrol)



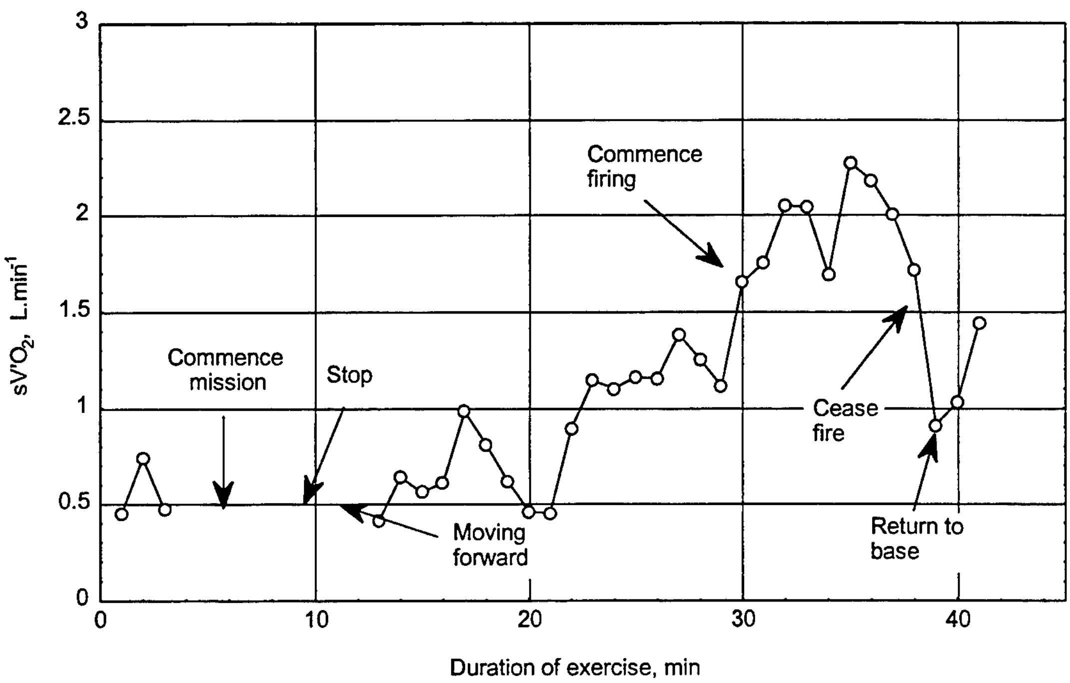
HRTA VO2, 8 February 1998 (HF3, Assault)

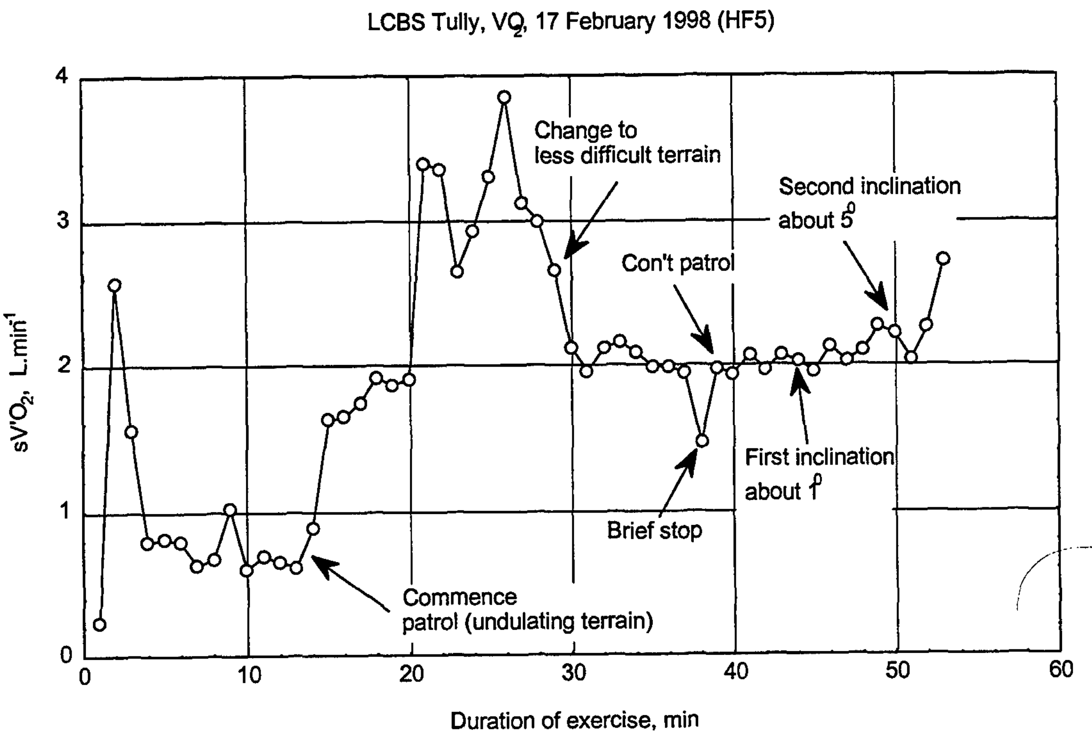


HRTA VO_2, 9 February 1998(HF4, Patrol)

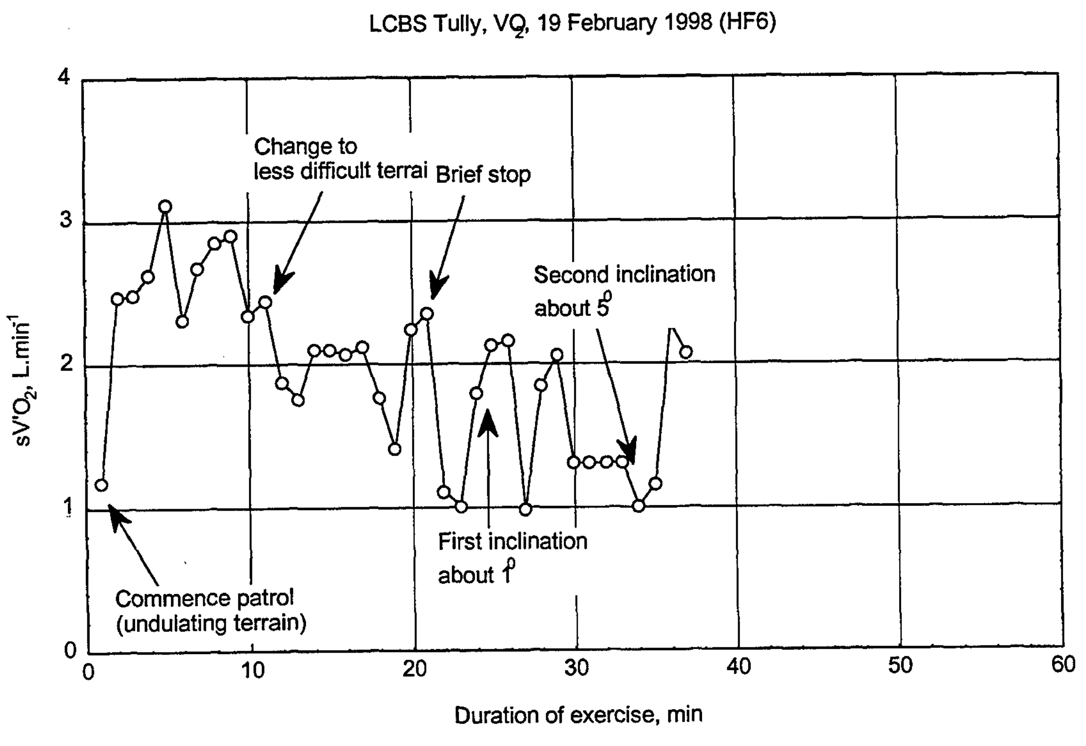


HRTA VO_2, 9 February 1998 (HF4, Assault)



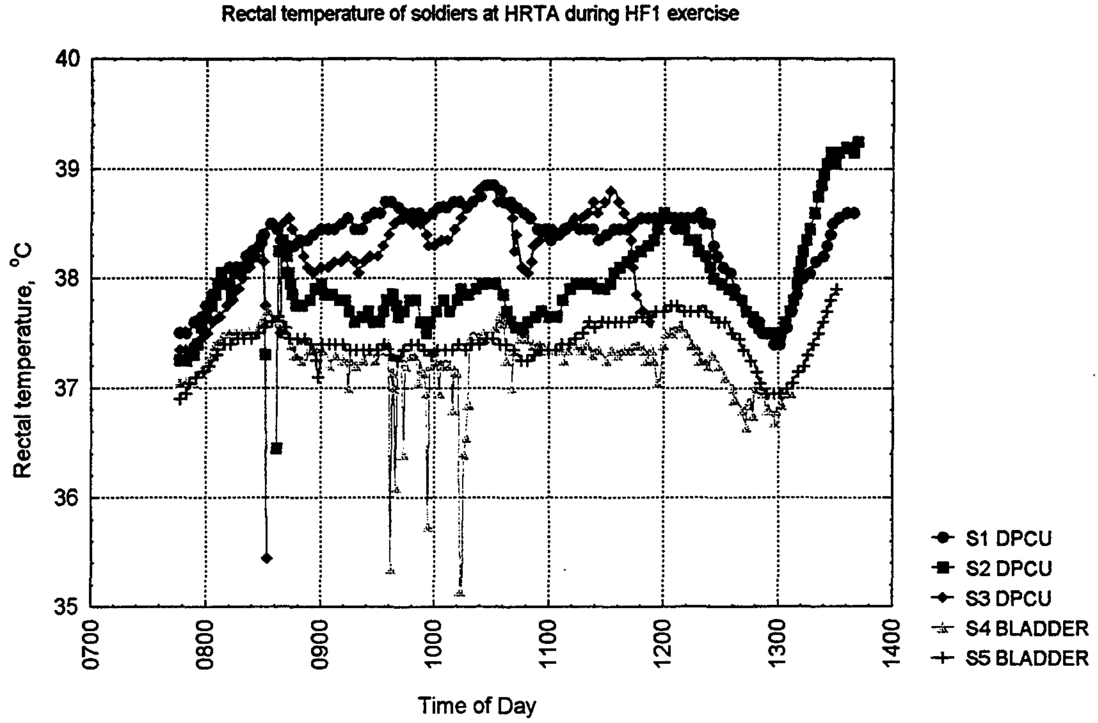


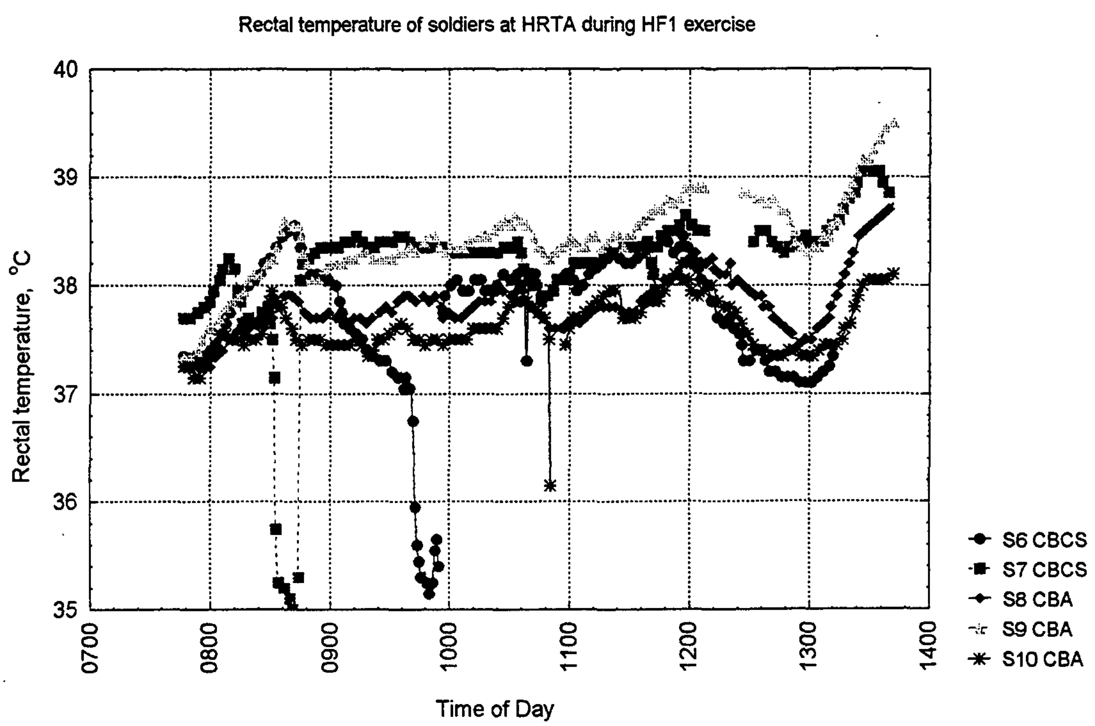
LCBS Tully, VO2, 17 February 1998 (HF5)
sV'O2, L.min-1
Duration of exercise, min
Change to
less difficult terrain
Second inclination
about 5°
Con't patrol
First inclination
about 1°
Brief stop
Commence
patrol (undulating terrain)

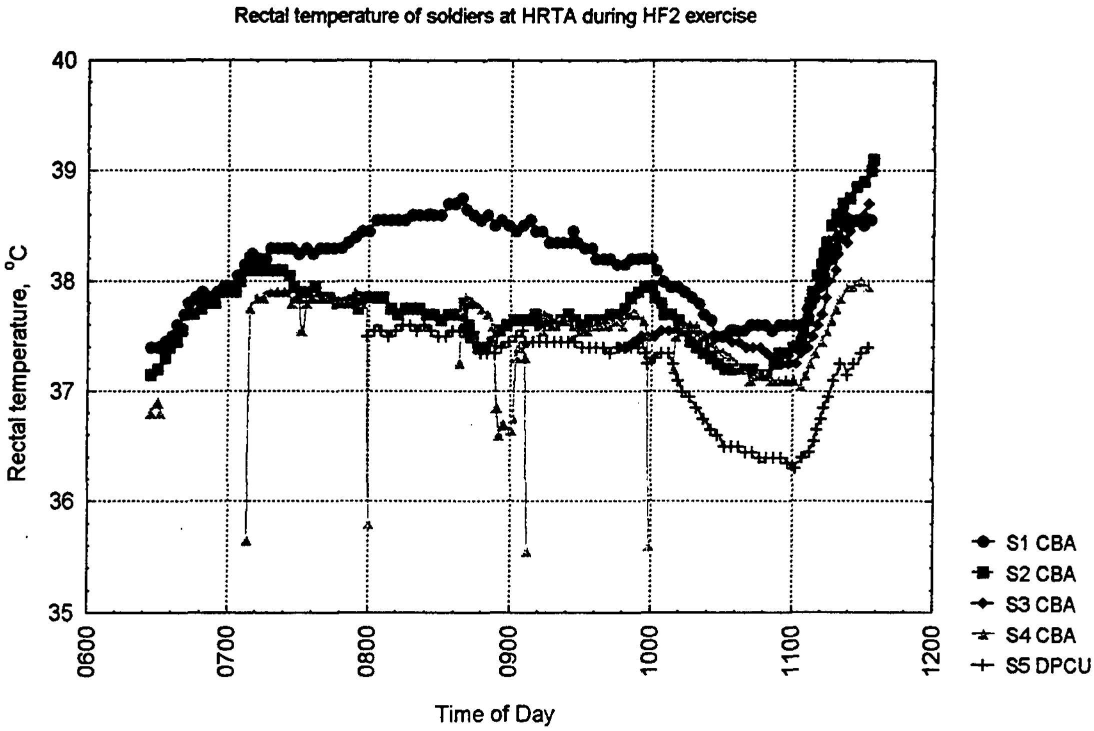


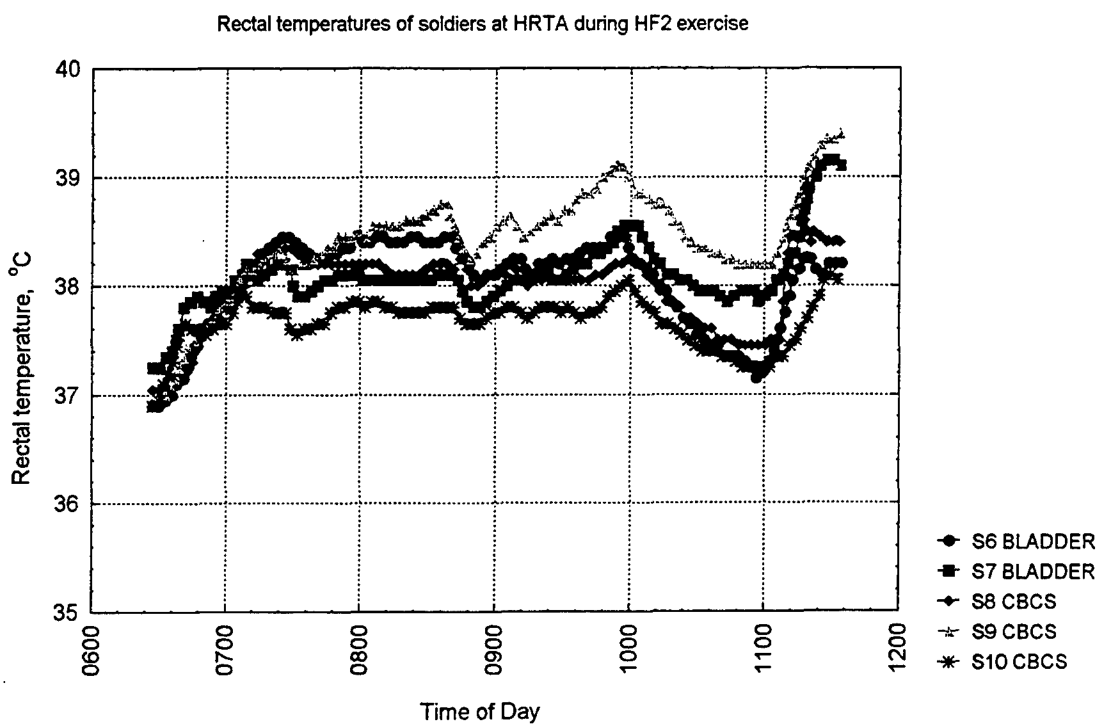
LCBS Tully, VO2, 19 February 1998 (HF6)
sV'O2, L.min-1
Duration of exercise, min
Change to
less difficult terrai
Brief stop
Second inclination
about 5°
First inclination
about 1°
Commence patrol
(undulating terrain)

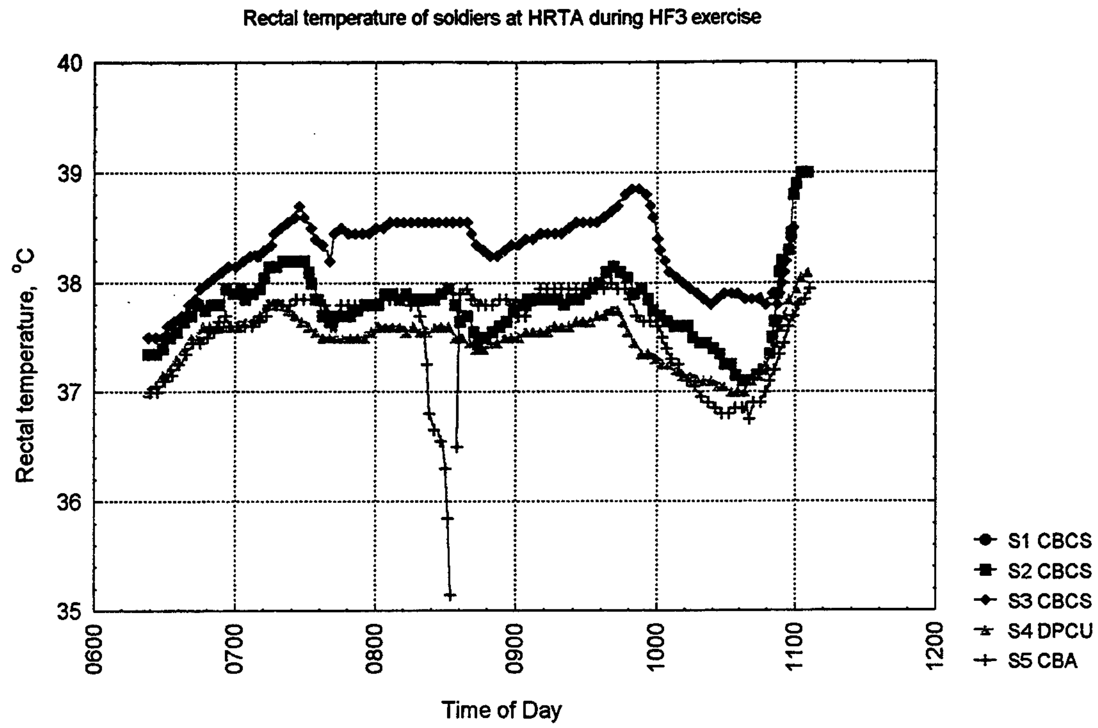
Appendix 5: Rectal Temperature During Exercise

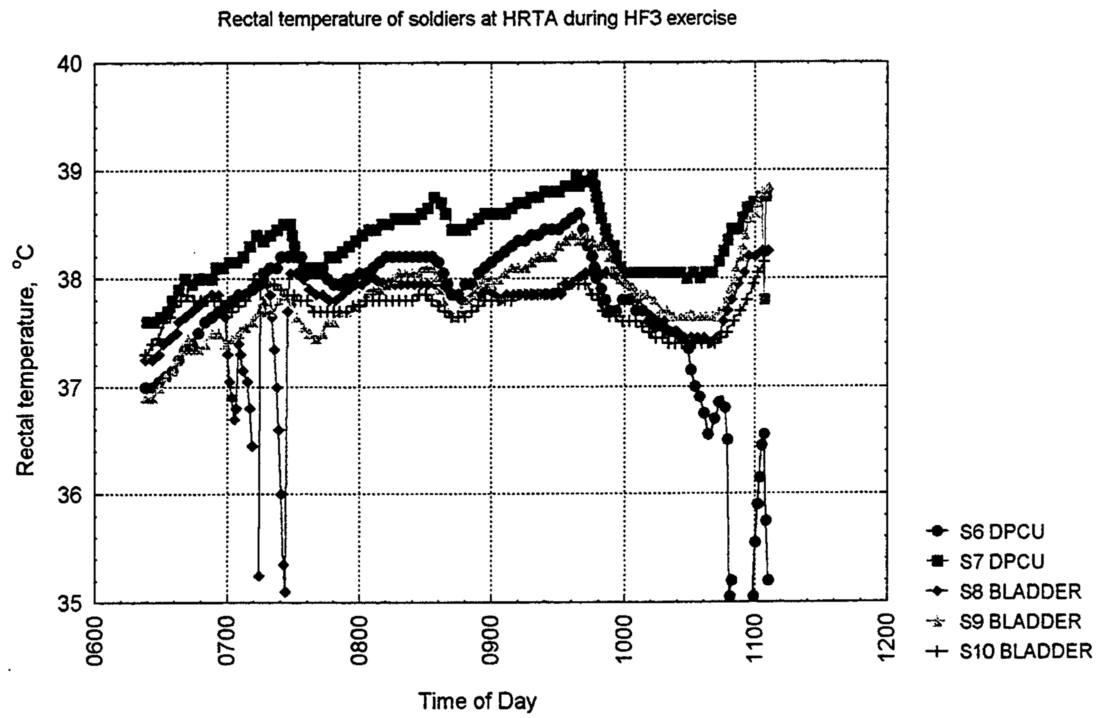


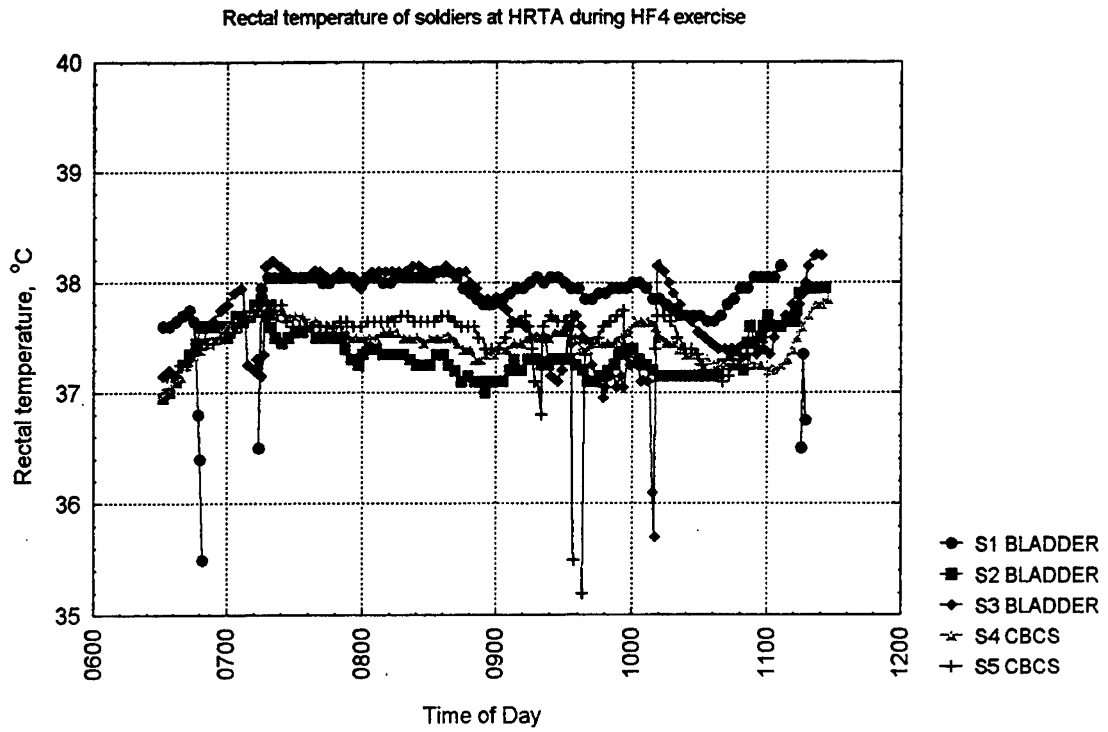


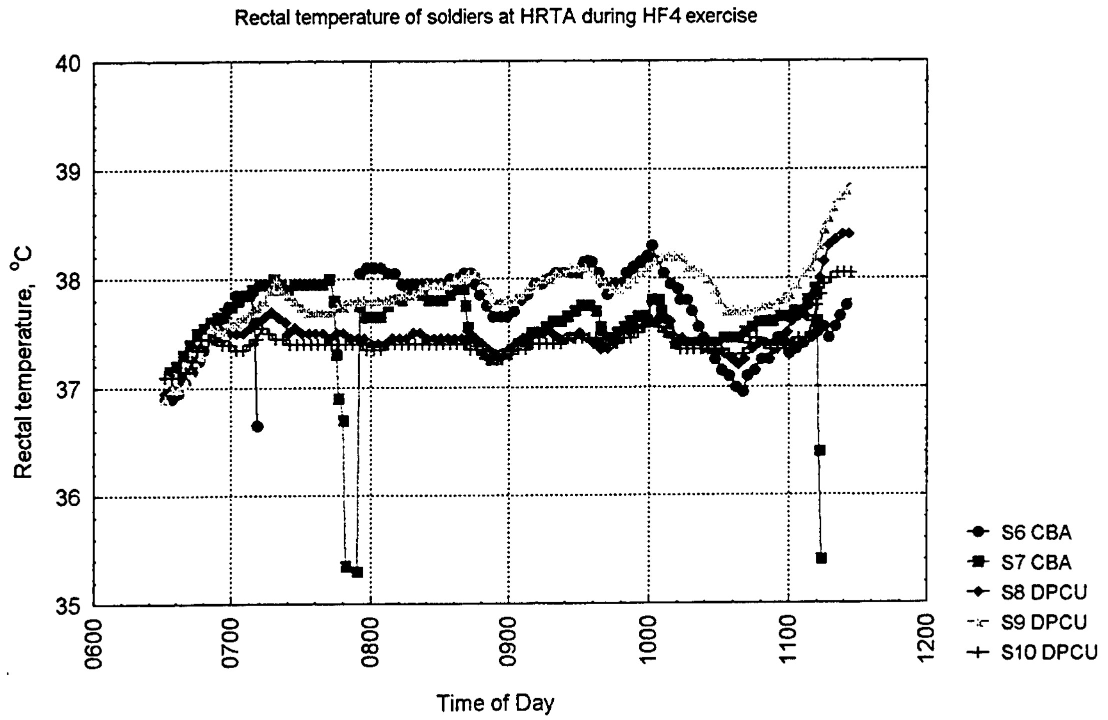

Rectal temperature of soldiers at HRTA during HF2 exercise
Rectal temperature, °C
40
39
38
37
36
35
0600
0700
0800
0900
1000
1100
1200
Time of Day
S1 CBA
S2 CBA
S3 CBA
S4 CBA
S5 DPCU


Rectal temperatures of soldiers at HRTA during HF2 exercise
Rectal temperature, °C
40
39
38
37
36
35
0600
0700
0800
0900
1000
1100
1200
Time of Day
S6 BLADDER
S7 BLADDER
S8 CBCS
S9 CBCS
S10 CBCS

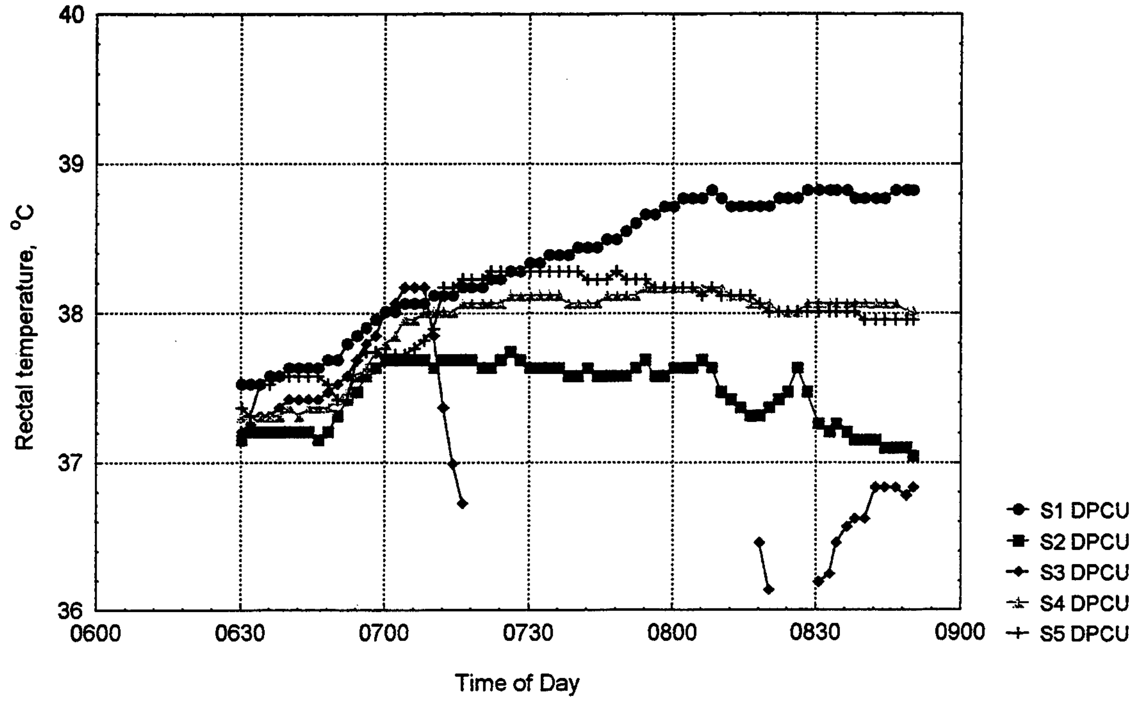

Rectal temperature of soldiers at HRTA during HF3 exercise
Rectal temperature, °C
40
39
38
37
36
35
0600
0700
0800
0900
1000
1100
1200
Time of Day
S1 CBCS
S2 CBCS
S3 CBCS
S4 DPCU
S5 CBA


Rectal temperature of soldiers at HRTA during HF3 exercise
Rectal temperature, °C
40
39
38
37
36
35
0600
0700
0800
0900
1000
1100
1200
Time of Day
S6 DPCU
S7 DPCU
S8 BLADDER
S9 BLADDER
S10 BLADDER

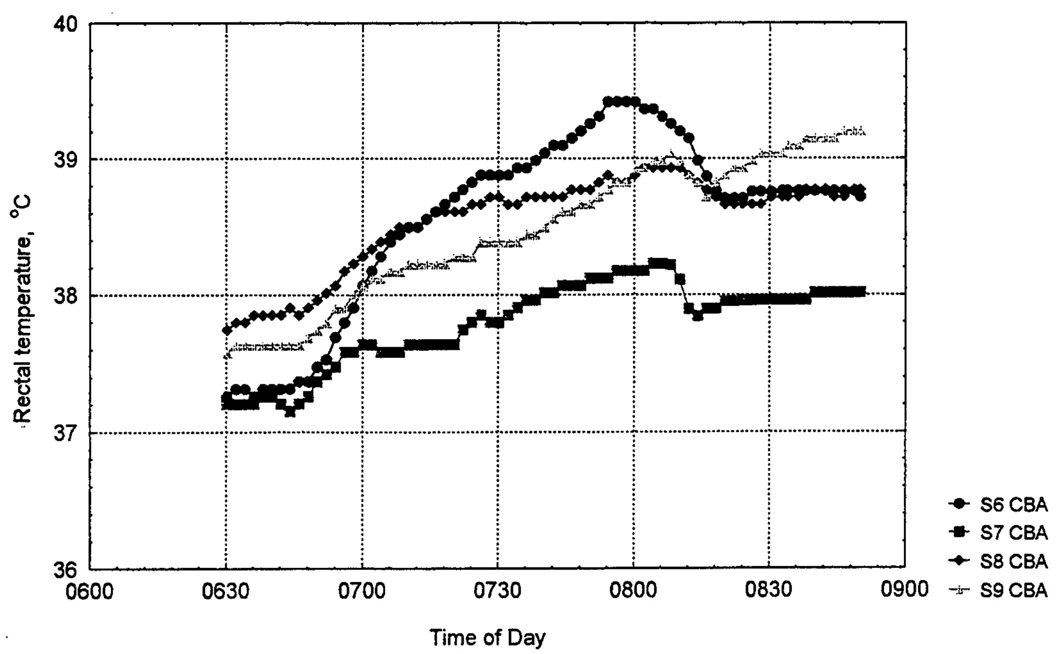

Rectal temperature of soldiers at HRTA during HF4 exercise
Rectal temperature, °C
40
39
38
37
36
35
0600
0700
0800
0900
1000
1100
1200
Time of Day
S1 BLADDER
S2 BLADDER
S3 BLADDER
S4 CBCS
S5 CBCS

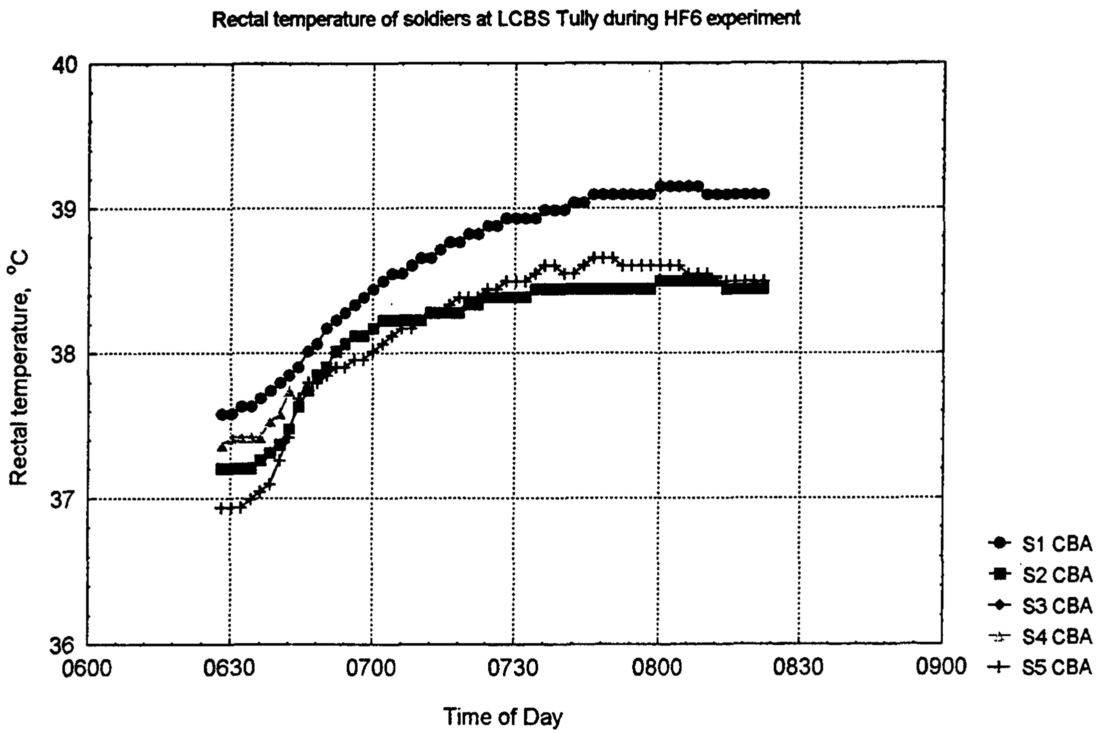

Rectal temperature of soldiers at HRTA during HF4 exercise
Rectal temperature, °C
40
39
38
37
36
35
0600
0700
0800
0900
1000
1100
1200
Time of Day
S6 CBA
S7 CBA
S8 DPCU
S9 DPCU
S10 DPCU

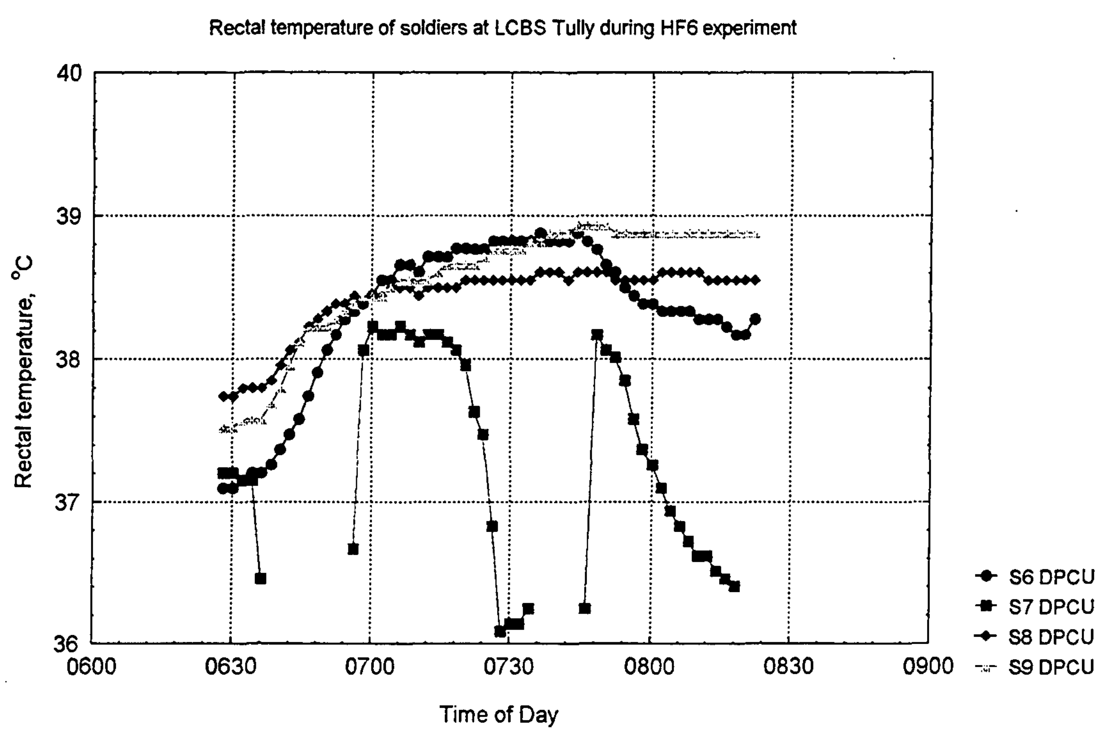
Rectal temperature of soldiers at LCBS Tully during HF5 experiment



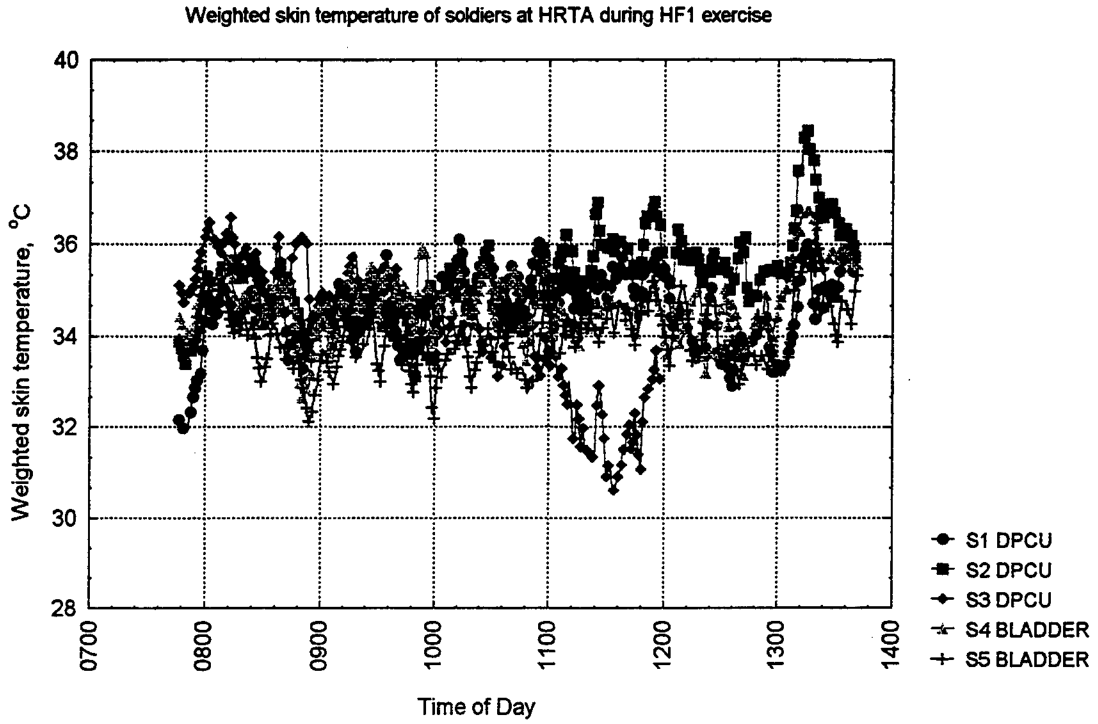
Rectal temperature of soldiers at LCBS Tully during HF5 experiment

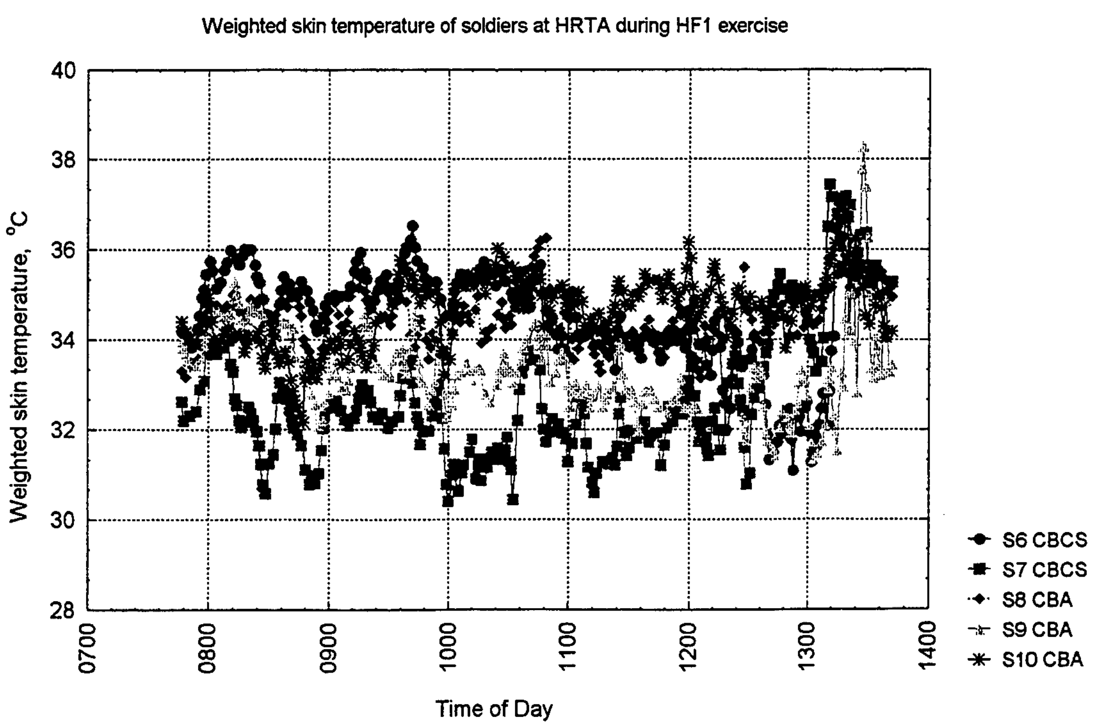


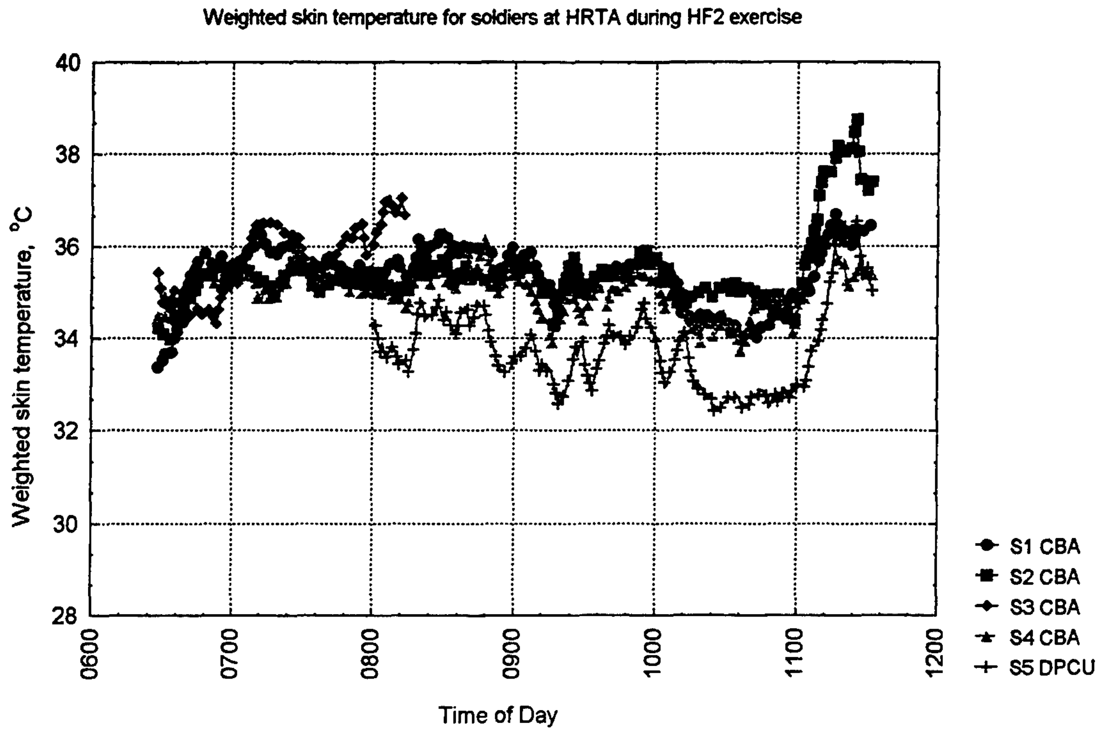

Rectal temperature of soldiers at LCBS Tully during HF6 experiment
40
39
38
37
36
Rectal temperature, °C
0600
0630
0700
0730
0800
0830
0900
Time of Day
S1 CBA
S2 CBA
S3 CBA
S4 CBA
S5 CBA

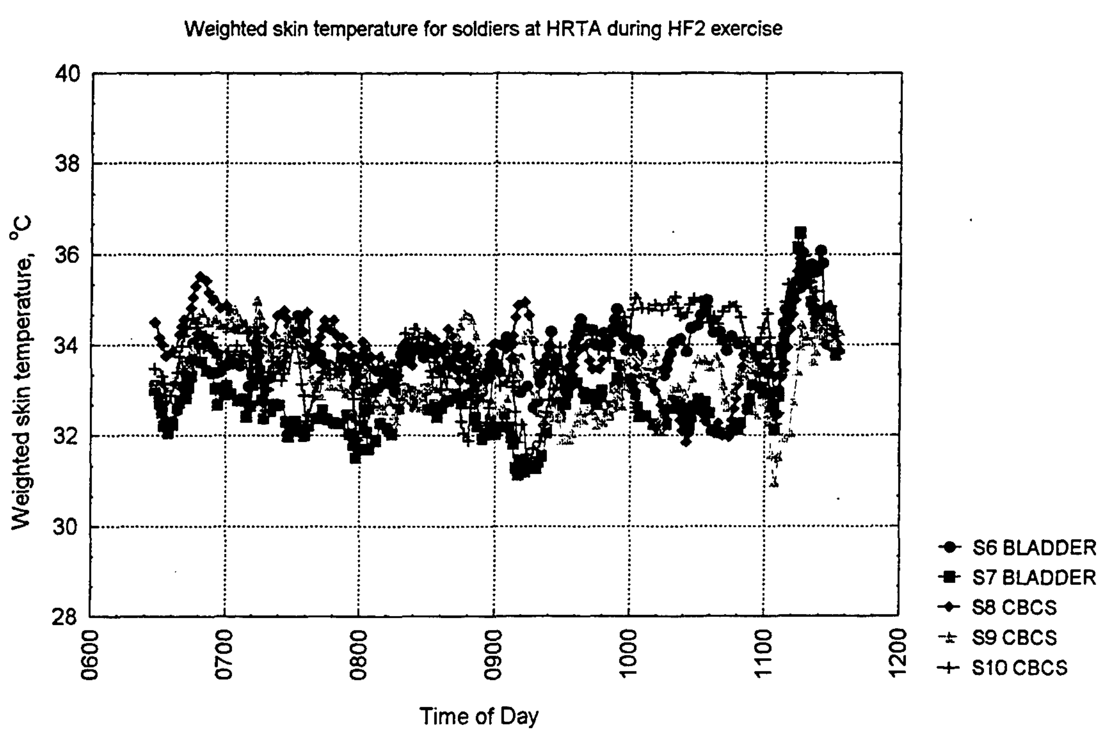

Rectal temperature of soldiers at LCBS Tully during HF6 experiment
40
39
38
37
36
Rectal temperature, °C
0600
0630
0700
0730
0800
0830
0900
Time of Day
S6 DPCU
S7 DPCU
S8 DPCU
S9 DPCU

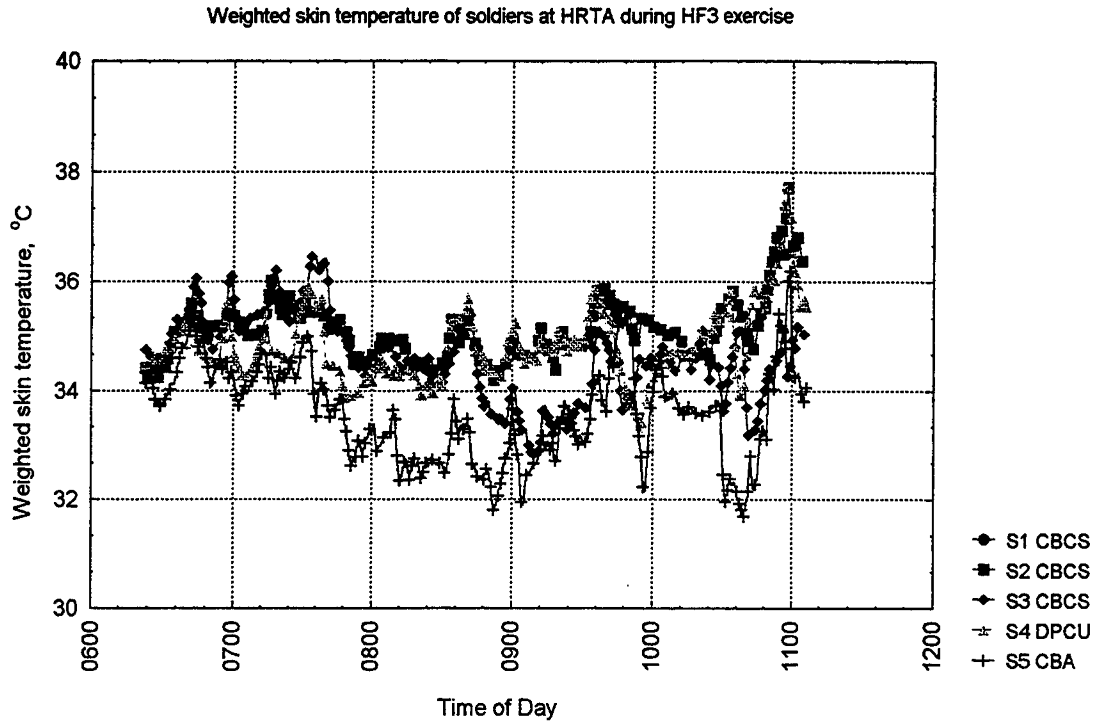
Appendix 6: Weighted Skin Temperature During Exercise

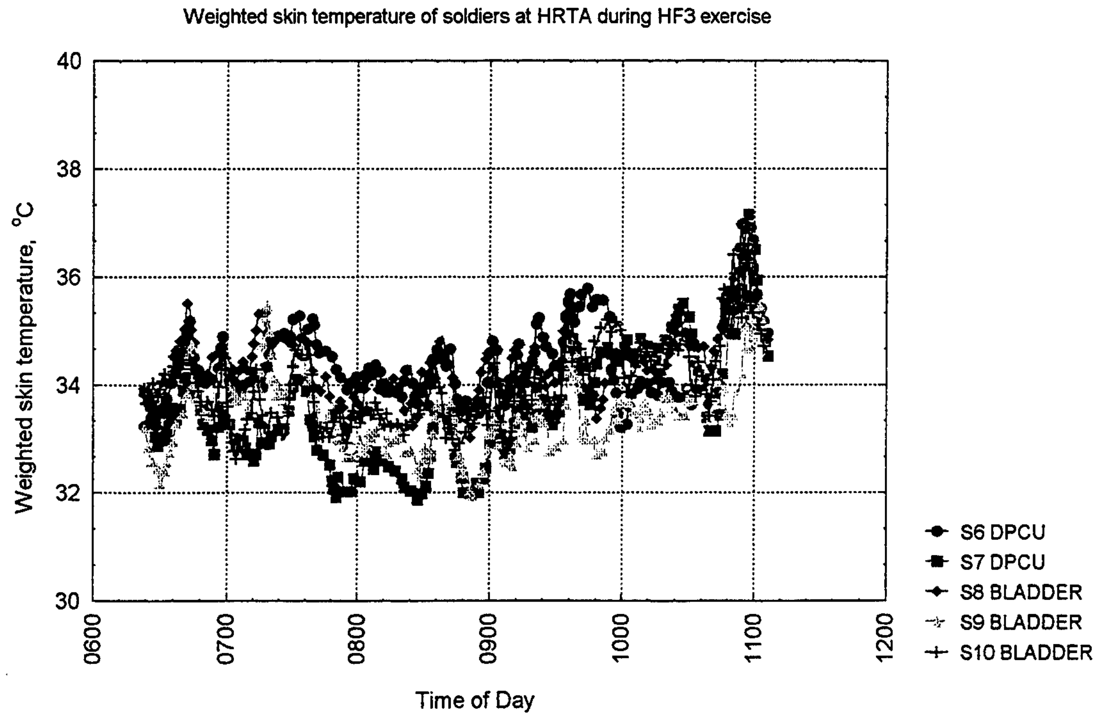


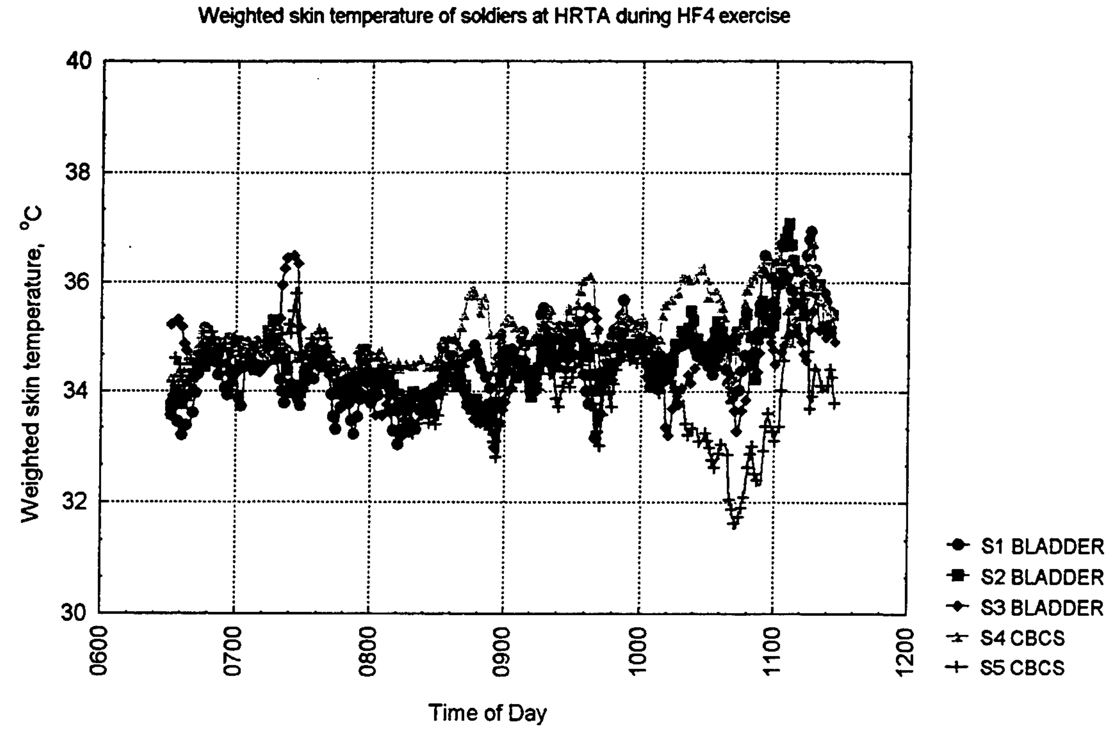


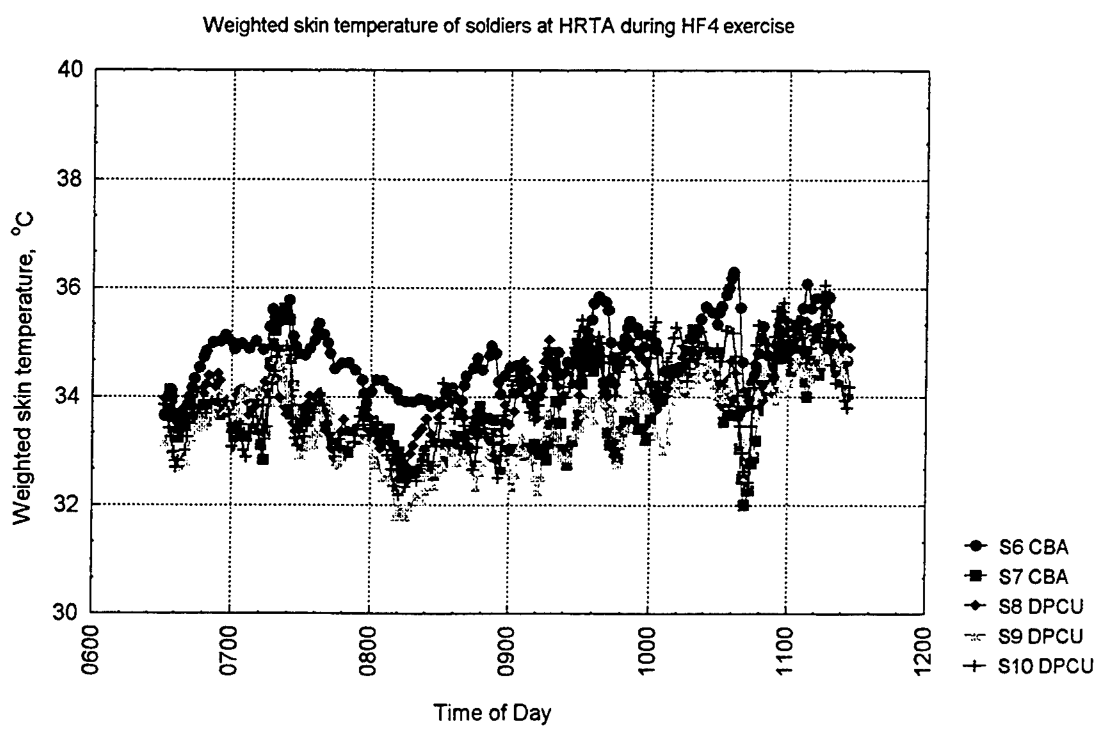

Weighted skin temperature for soldiers at HRTA during HF2 exercise
Weighted skin temperature, °C
40
38
36
34
32
30
28
0600
0700
0800
0900
1000
1100
1200
Time of Day
S1 CBA
S2 CBA
S3 CBA
S4 CBA
S5 DPCU

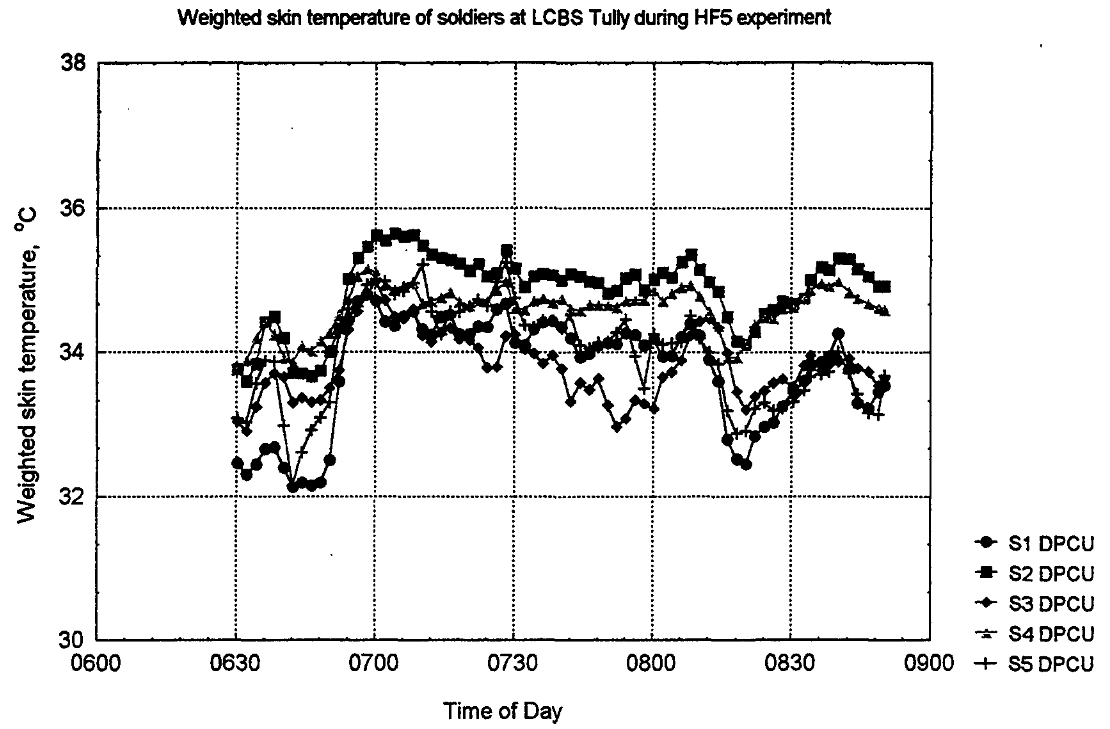

Weighted skin temperature for soldiers at HRTA during HF2 exercise
Weighted skin temperature, °C
40
38
36
34
32
30
28
0600
0700
0800
0900
1000
1100
1200
Time of Day
S6 BLADDER
S7 BLADDER
S8 CBCS
S9 CBCS
S10 CBCS

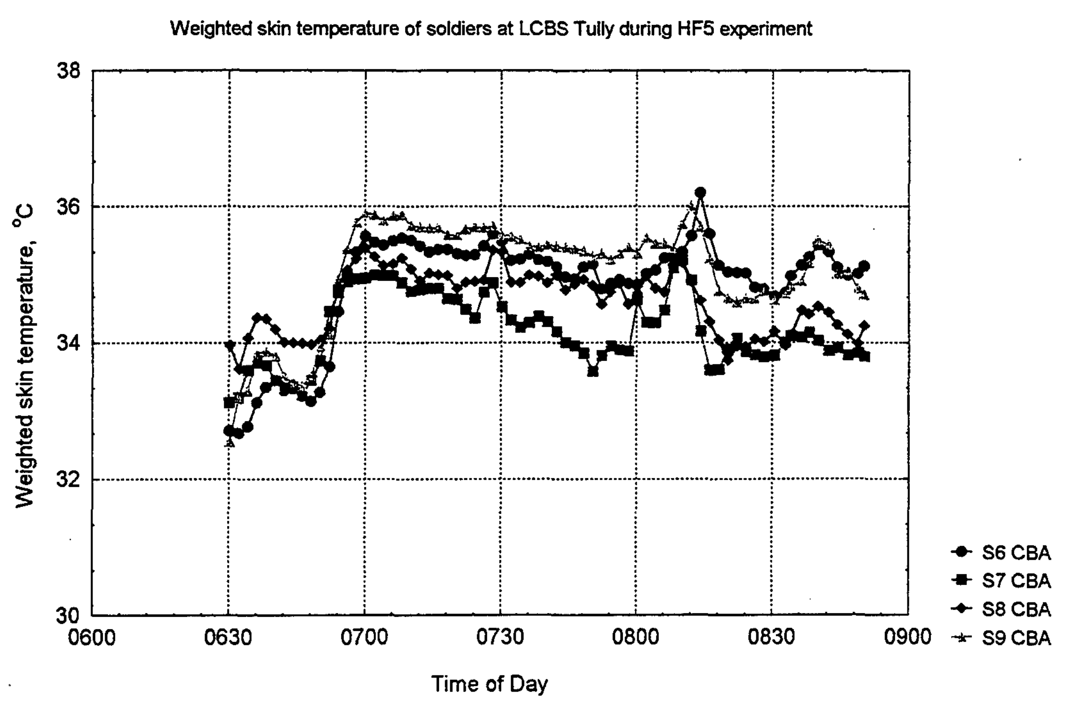

Weighted skin temperature of soldiers at HRTA during HF3 exercise
Weighted skin temperature, °C
40
38
36
34
32
30
0600
0700
0800
0900
1000
1100
1200
Time of Day
S1 CBCS
S2 CBCS
S3 CBCS
S4 DPCU
S5 CBA

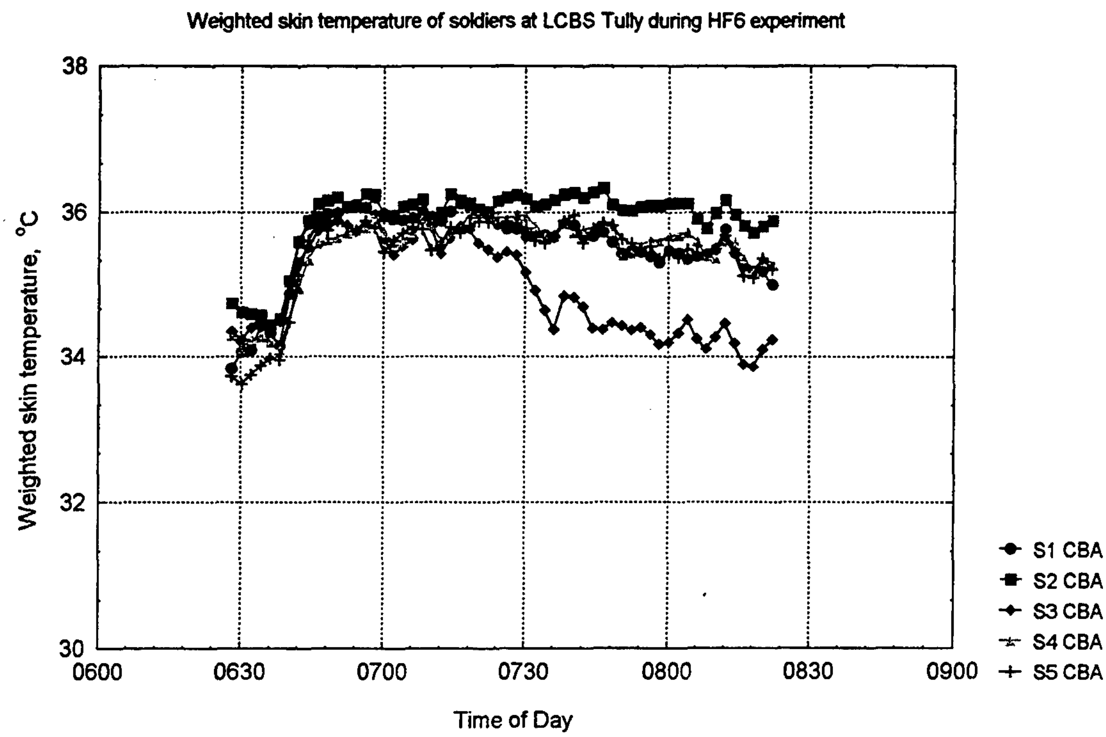

Weighted skin temperature of soldiers at HRTA during HF3 exercise
Weighted skin temperature, °C
40
38
36
34
32
30
0600
0700
0800
0900
1000
1100
1200
Time of Day
S6 DPCU
S7 DPCU
S8 BLADDER
S9 BLADDER
S10 BLADDER

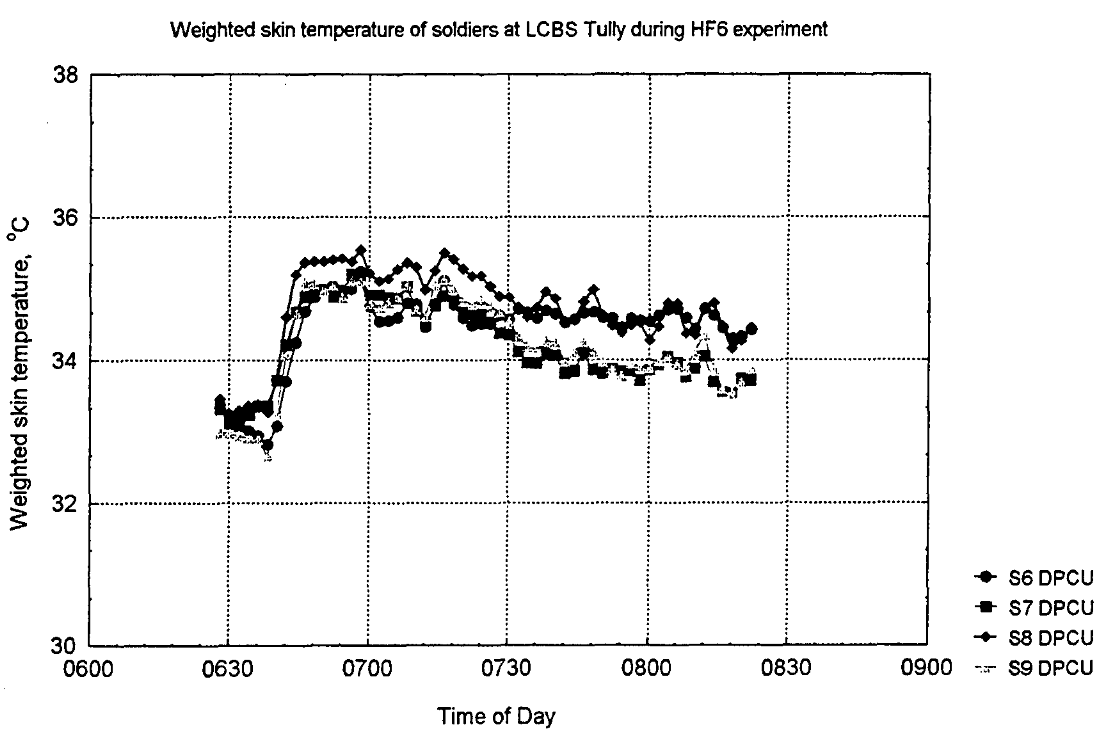

Weighted skin temperature of soldiers at HRTA during HF4 exercise
Weighted skin temperature, °C
40
38
36
34
32
30
0600
0700
0800
0900
1000
1100
1200
Time of Day
S1 BLADDER
S2 BLADDER
S3 BLADDER
S4 CBCS
S5 CBCS


Weighted skin temperature of soldiers at HRTA during HF4 exercise
Weighted skin temperature, °C
40
38
36
34
32
30
0600
0700
0800
0900
1000
1100
1200
Time of Day
S6 CBA
S7 CBA
S8 DPCU
S9 DPCU
S10 DPCU

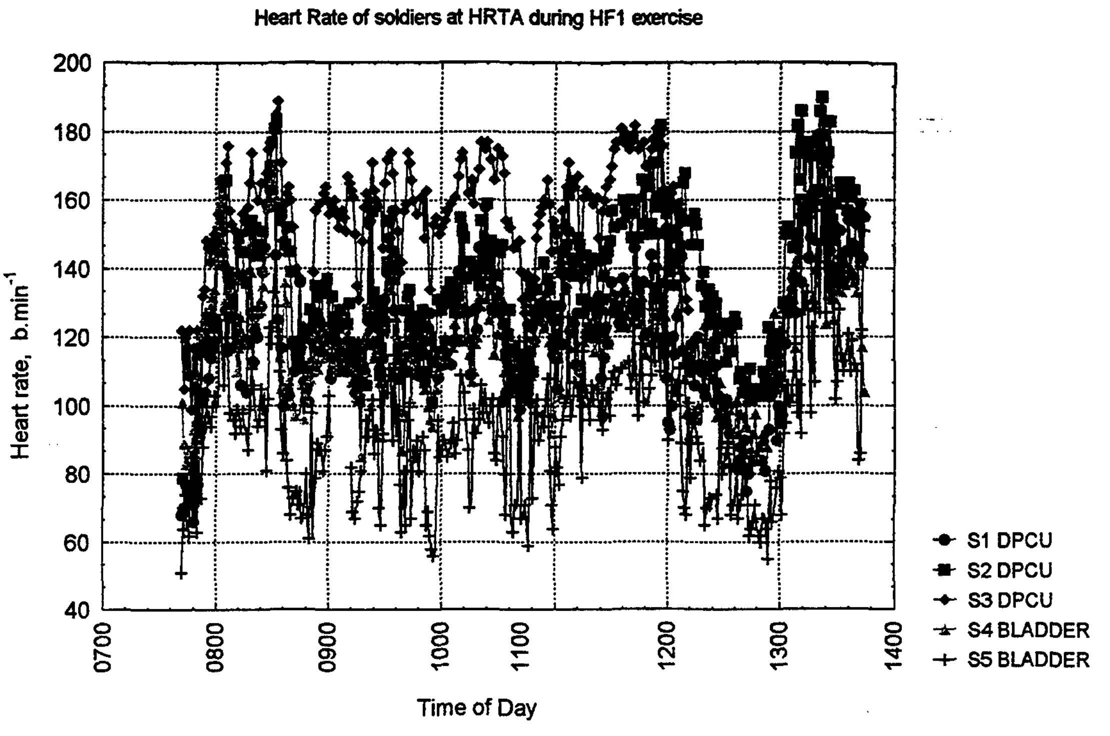

Weighted skin temperature of soldiers at LCBS Tully during HF5 experiment
Weighted skin temperature, °C
38
36
34
32
30
0600
0630
0700
0730
0800
0830
0900
Time of Day
S1 DPCU
S2 DPCU
S3 DPCU
S4 DPCU
S5 DPCU

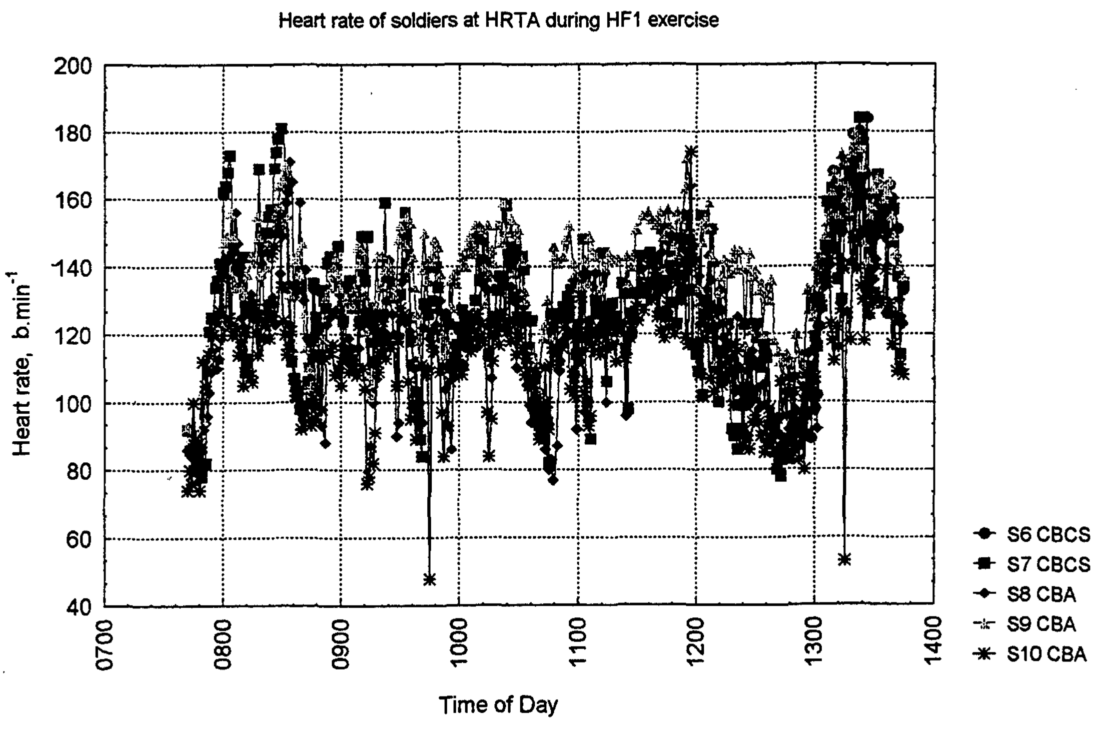

Weighted skin temperature of soldiers at LCBS Tully during HF5 experiment
Weighted skin temperature, °C
38
36
34
32
30
0600
0630
0700
0730
0800
0830
0900
Time of Day
S6 CBA
S7 CBA
S8 CBA
S9 CBA

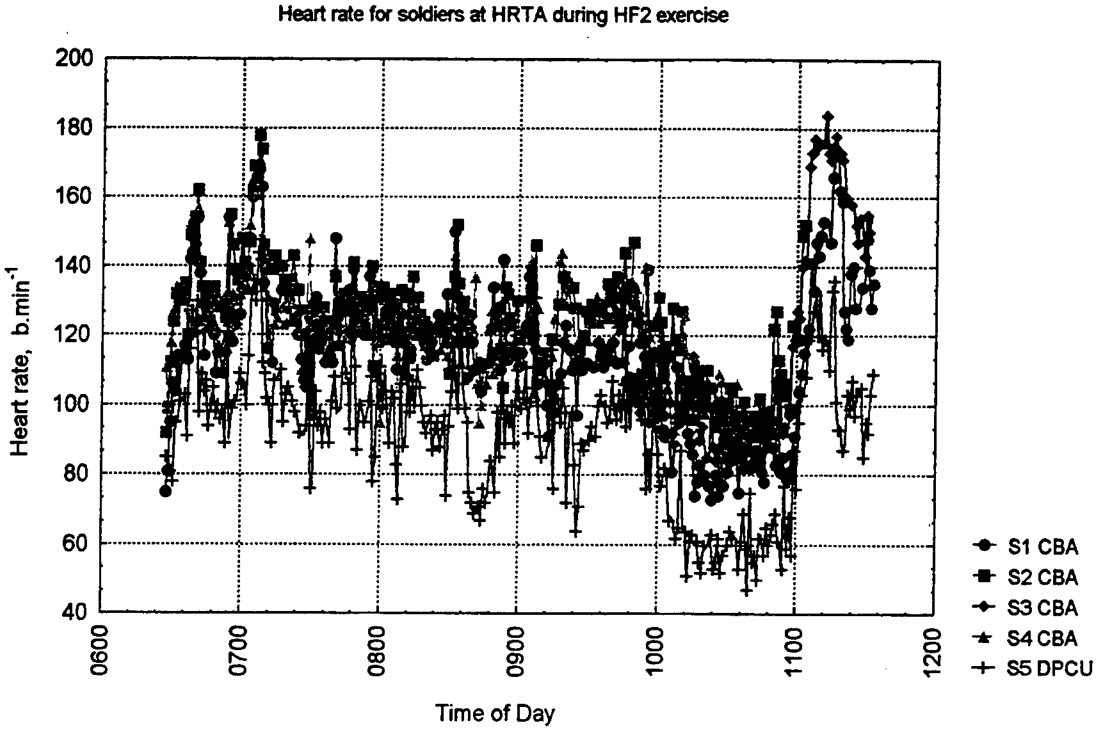

Weighted skin temperature of soldiers at LCBS Tully during HF6 experiment
Weighted skin temperature, °C
38
36
34
32
30
0600
0630
0700
0730
0800
0830
0900
Time of Day
S1 CBA
S2 CBA
S3 CBA
S4 CBA
S5 CBA

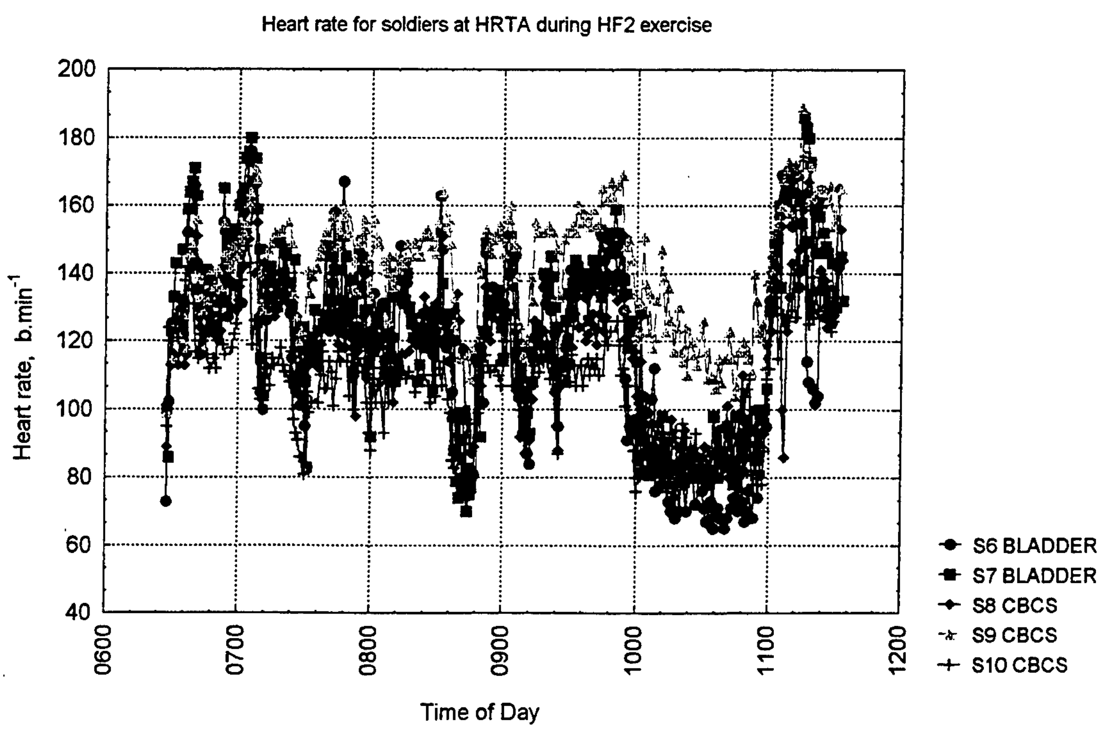

Weighted skin temperature of soldiers at LCBS Tully during HF6 experiment
Weighted skin temperature, °C
38
36
34
32
30
0600
0630
0700
0730
0800
0830
0900
Time of Day
S6 DPCU
S7 DPCU
S8 DPCU
S9 DPCU

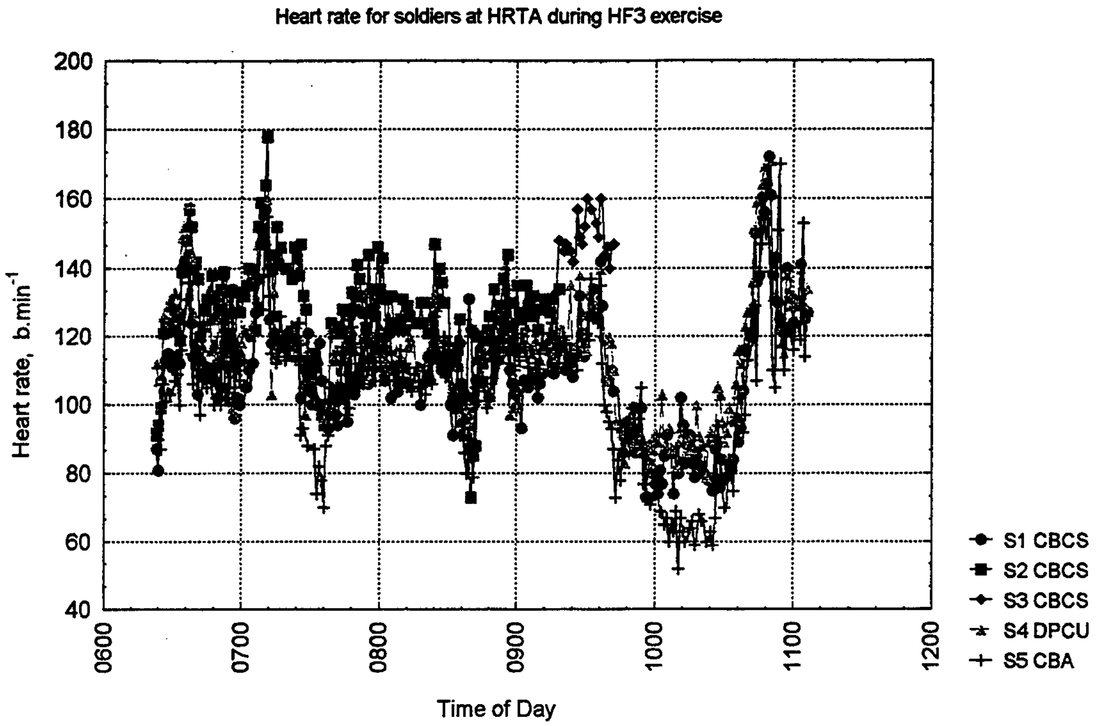
Appendix 7: Heart Rate During Exercise

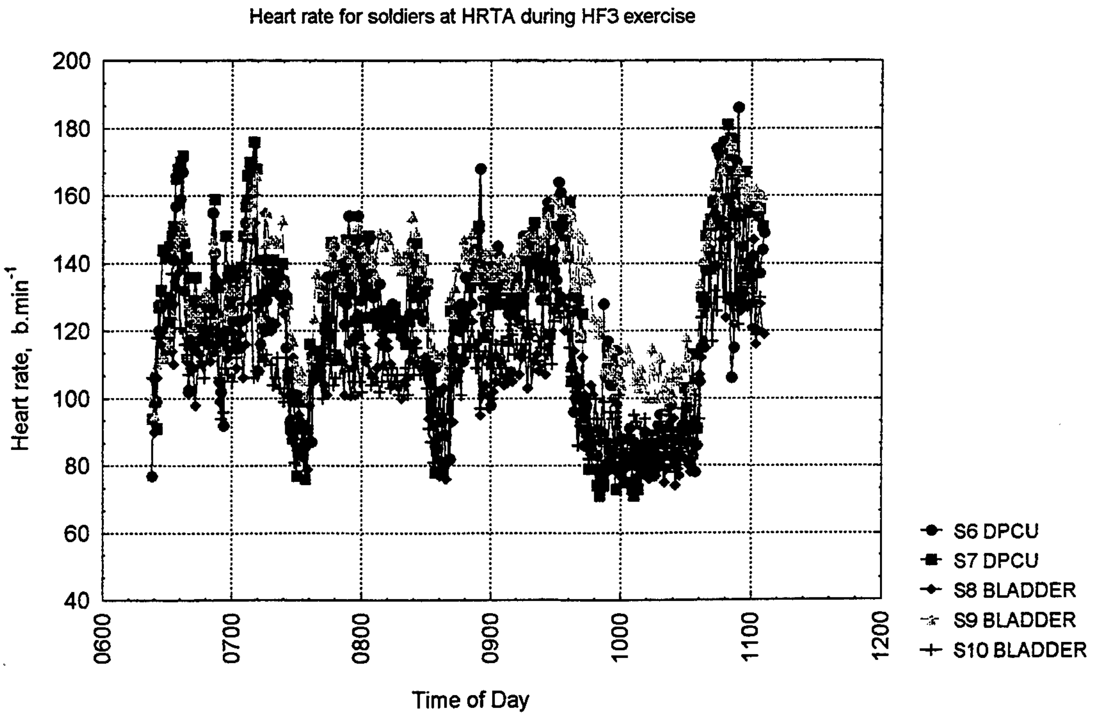


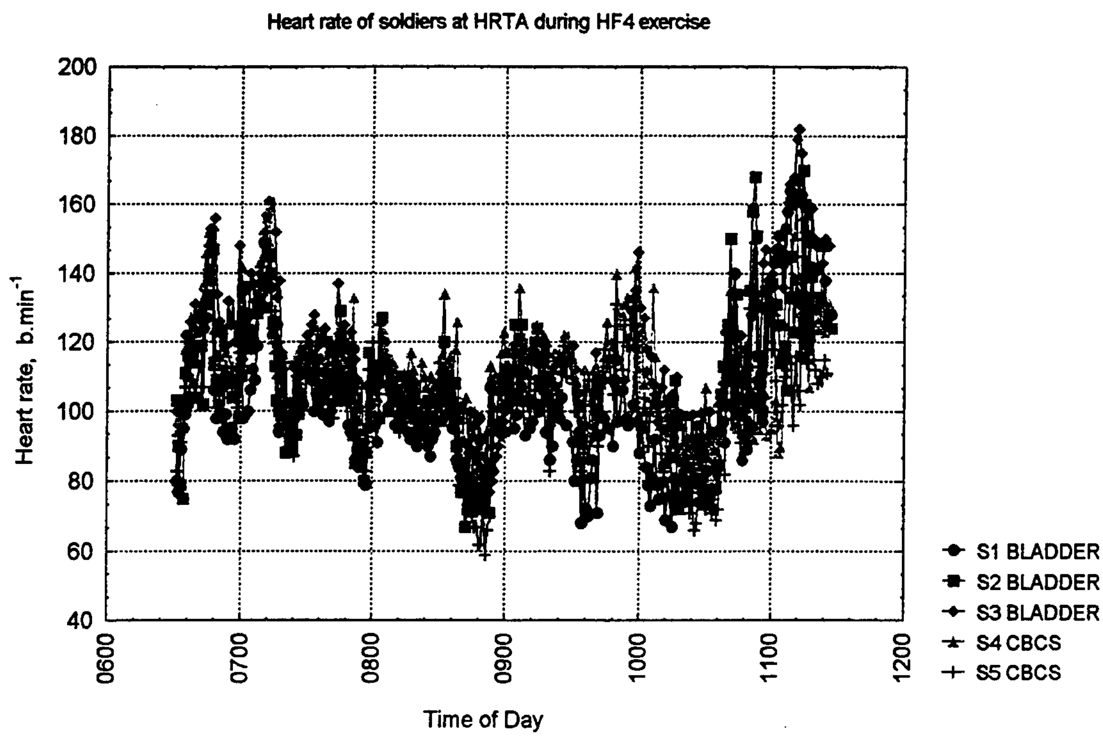


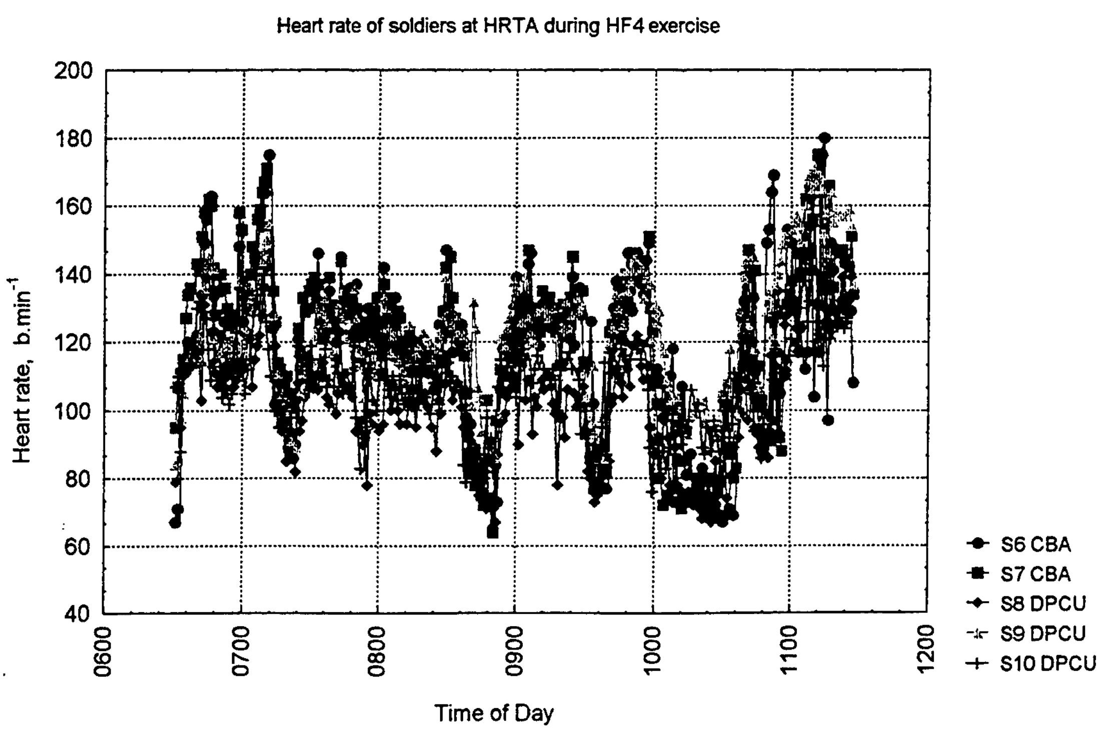

Heart rate for soldiers at HRTA during HF2 exercise
200
180
160
140
120
100
80
60
40
Heart rate, b.min-1
0600
0700
0800
0900
1000
1100
1200
Time of Day
S1 CBA
S2 CBA
S3 CBA
S4 CBA
S5 DPCU

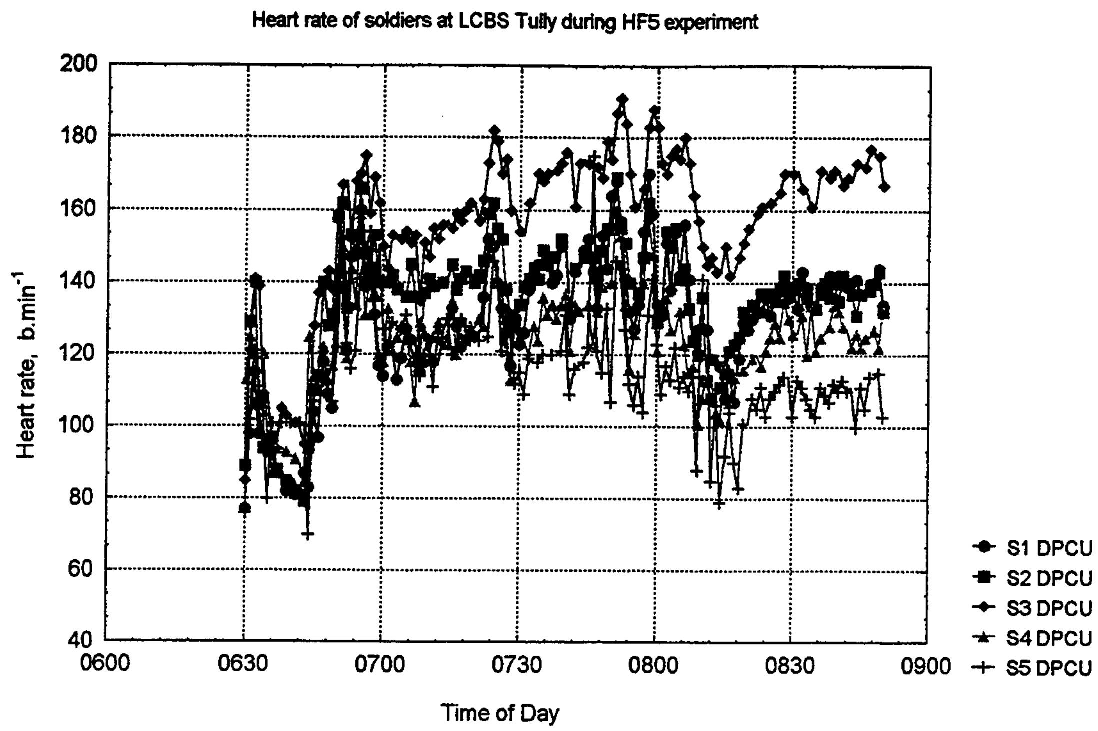

Heart rate for soldiers at HRTA during HF2 exercise
200
180
160
140
120
100
80
60
40
Heart rate, b.min-1
0600
0700
0800
0900
1000
1100
1200
Time of Day
S6 BLADDER
S7 BLADDER
S8 CBCS
S9 CBCS
S10 CBCS

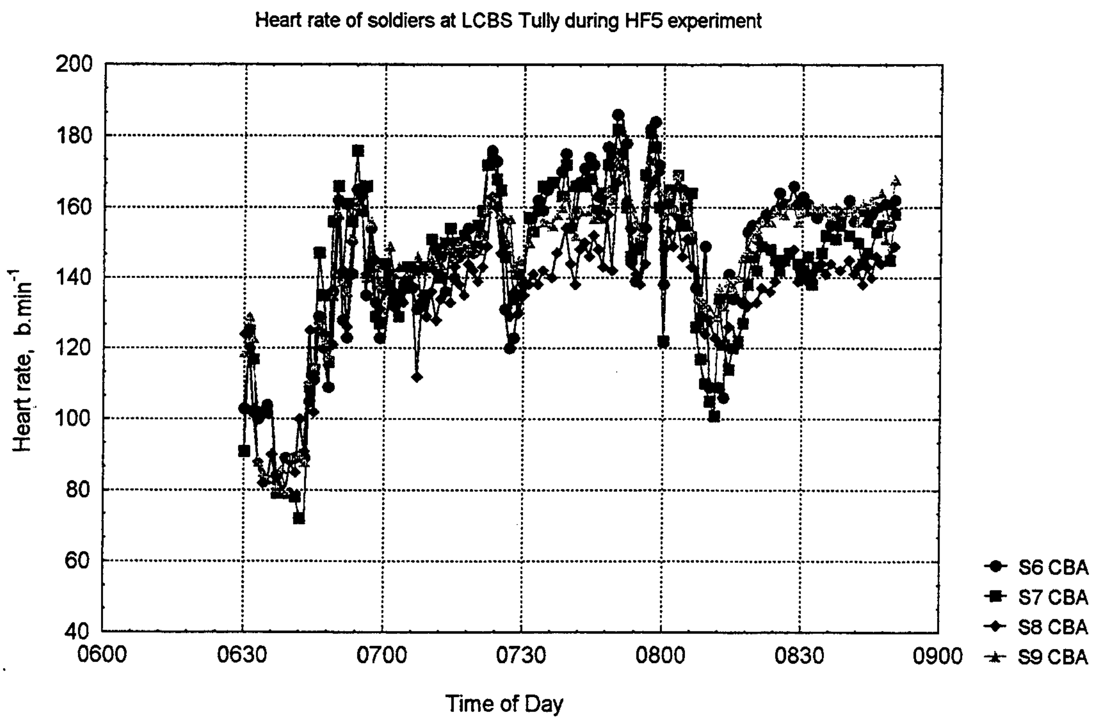

Heart rate for soldiers at HRTA during HF3 exercise
Heart rate, b.min-1
200
180
160
140
120
100
80
60
40
0600
0700
0800
0900
1000
1100
1200
Time of Day
S1 CBCS
S2 CBCS
S3 CBCS
S4 DPCU
S5 CBA

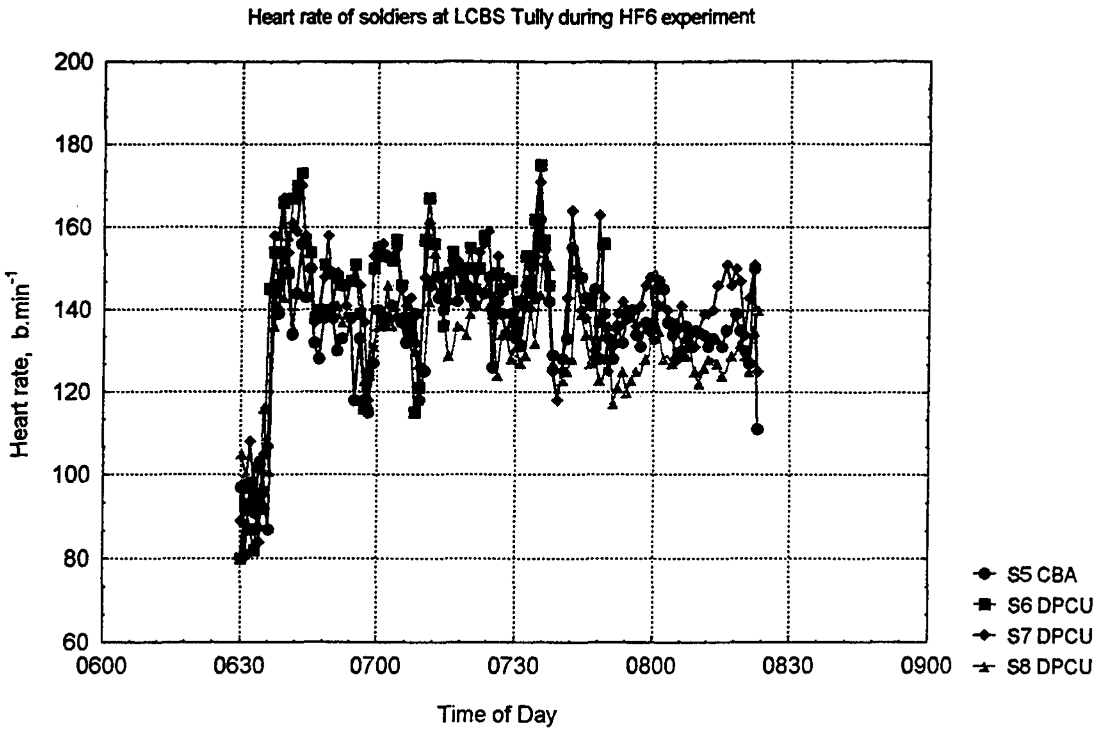

Heart rate for soldiers at HRTA during HF3 exercise
Heart rate, b.min-1
200
180
160
140
120
100
80
60
40
0600
0700
0800
0900
1000
1100
1200
Time of Day
S6 DPCU
S7 DPCU
S8 BLADDER
S9 BLADDER
S10 BLADDER


Heart rate of soldiers at HRTA during HF4 exercise
200
180
160
140
120
100
80
60
40
Heart rate, b.min-1
0600
0700
0800
0900
1000
1100
1200
Time of Day
S1 BLADDER
S2 BLADDER
S3 BLADDER
S4 CBCS
S5 CBCS


Heart rate of soldiers at HRTA during HF4 exercise
200
180
160
140
120
100
80
60
40
Heart rate, b.min-1
0600
0700
0800
0900
1000
1100
1200
Time of Day
S6 CBA
S7 CBA
S8 DPCU
S9 DPCU
S10 DPCU


Heart rate of soldiers at LCBS Tully during HF5 experiment
Heart rate, b.min^{-1}
200
180
160
140
120
100
80
60
40
0600
0630
0700
0730
0800
0830
0900
Time of Day
S1 DPCU
S2 DPCU
S3 DPCU
S4 DPCU
S5 DPCU


Heart rate of soldiers at LCBS Tully during HF5 experiment
Heart rate, b.min^{-1}
200
180
160
140
120
100
80
60
40
0600
0630
0700
0730
0800
0830
0900
Time of Day
S6 CBA
S7 CBA
S8 CBA
S9 CBA


Heart rate of soldiers at LCBS Tully during HF6 experiment
Heart rate, b.min-1
200
180
160
140
120
100
80
60
0600
0630
0700
0730
0800
0830
0900
Time of Day
S5 CBA
S6 DPCU
S7 DPCU
S8 DPCU

Appendix 8: Hydration: Raw Data

Hydration: Raw data for HF1-HF4 (HRTA)

HF1, HRTA, 6 FEB 98, RAW DATA

PRE-PATROL (NOTE: SUBJECT # 3 WAS WITHDRAWN DUE TO HEAT STRESS)

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	BREAK-FAST EATEN (KG)	INITIAL WATER (L)	WATER DRUNK PRE-PATROL (L)
S1	DPCU	C	78.60	81.95	99.10	0.00	4.20	0.45
S2	DPCU	C	73.10	76.30	97.80	0.00	4.10	0.50
S4	DPCU	ST	75.50	79.05	103.95	0.00	4.25	1.00
S5	DPCU	ST	84.90	88.75	108.05	0.00	4.30	3.00
S6	CBCS	C	77.85	81.80	112.75	0.00	4.30	0.85
S7	CBCS	C	69.30	73.45	95.10	0.00	3.85	0.00
S8	CBA	C	68.10	73.50	92.55	0.00	4.20	0.95
S9	CBA	C	89.80	96.05	116.55	0.00	4.10	0.95
S10	CBA	C	71.55	77.20	93.10	0.00	4.35	0.00
MEAN			76.52	80.89	102.11	0.00	4.18	0.86
SD			7.19	7.43	8.73	0.00	0.15	0.89

MID EXPERIMENT (First phase - slow patrol - finished 4.27 hours after commencement)

NO	MAG (INITIAL) (KG)	URINE PRE-PATROL (L)	WEIGHT BEFORE RESUP (KG)	WEIGHT POST RESUP (KG)	WATER PRE-RESUP (KG)	WATER POST RESUP (KG)	WATER INTAKE TO OP (KG)	URINE PROD TO OP (KG)
S1	1.80	0.07	94.85	96.90	2.35	4.25	1.85	0.22
S2	1.80	0.04	93.80	97.15	0.45	4.35	3.65	0.14
S4	1.75	0.03	99.85	102.65	1.80	4.50	2.45	0.09
S5	1.80	0.04	102.05	104.70	2.00	4.15	2.30	0.66
S6	3.25	0.00	108.15	111.00	1.35	4.30	2.95	0.14
S7	2.10	0.12	91.45	95.00	0.75	4.30	3.10	0.17
S8	1.80	0.11	88.95	96.20	1.90	3.85	2.30	0.00
S9	1.80	0.07	109.25	113.00	0.45	4.25	3.65	0.12
S10	1.90	0.08	89.75	91.25	2.75	4.25	1.60	0.07
MEAN	2.00	0.06	97.57	100.87	1.53	4.24	2.65	0.18
SD	0.48	0.04	7.65	7.47	0.83	0.18	0.73	0.19

POST PATROL (Second phase consisted of 57 min of rest and 37 min of patrol/assault)

NO	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	FINAL WATER (KG)	WATER INTAKE FROM OP (KG)	MAG FINAL (KG)	POST PATROL URINE (KG)	TOTAL WATER DRUNK (KG)	TOTAL SWEAT PROD (KG)	TOTAL URINE PROD (KG)
S1	76.20	80.50	94.75	2.55	1.70	1.30	0.04	3.55	5.62	0.33
S2	72.25	76.10	95.00	2.95	1.40	0.95	NA#	5.05	5.72	0.18
S4	74.05	78.15	100.85	2.80	1.70	1.75	0.19	4.15	5.29	0.31
S5	83.50	88.30	102.10	2.45	1.70	1.05	0.08	4.00	4.62	0.78
S6	74.85	79.80	105.15	3.55	0.75	1.70	0.02	3.70	6.54	0.16
S7	67.65	73.05	93.75	3.20	1.10	1.00	0.08	4.20	5.48	0.37
S8	66.35	72.05	92.90	2.40	1.45	4.25	0.07	3.75	5.32	0.18
S9	85.00	92.00	110.30	2.70	1.55	1.10	0.02	5.20	9.79	0.21
S10	69.35	75.70	88.15	4.25	0.00	0.95	0.05	1.60	3.60	0.20
MEAN	74.36	79.52	98.11	2.98	1.26	1.56	0.07	3.91	5.78	0.30
SD	6.51	6.71	6.96	0.60	0.57	1.05	0.05	1.04	1.71	0.19

Hydration: Raw data for HF1-HF4 (HRTA) (continued)

HF2, HRTA, 7 FEB 98, RAW DATA

PRE-PATROL

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	NUDE WEIGHT (KG)	CLOTHE WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	BREAK-FAST EATEN (KG)	INITIAL WATER (L)	WATER DRUNK PRE-PAT (L)	MAG (INITIAL) (KG)	URINE PRE-PATROL (L)#
S1	CBA	C	78.00	83.90	100.90	0.41	4.30	0.50	1.80	NA
S2	CBA	C	73.30	80.80	101.15	0.41	4.30	0.85	2.40	NA
S4	CBA	C	75.75	81.80	105.80	0.41	4.30	0.50	2.35	NA
S5	DPCU	C	83.85	87.75	106.00	0.41	4.30	3.00	2.25	NA
S6	DPCU	ST	76.30	79.30	106.45	0.41	4.30	0.50	7.30	NA
S7	DPCU	ST	68.30	71.30	91.20	0.35	4.30	0.50	2.45	NA
S8	CBCS	C	66.95	71.30	87.75	0.38	4.30	0.50	2.50	NA
S9	CBCS	C	87.15	92.05	113.55	0.41	4.30	0.50	2.25	NA
S10	CBCS	C	70.70	75.00	90.55	0.47	4.30	0.50	2.05	NA
MEAN			75.59	80.36	100.37	0.41	4.30	0.82	2.82	NA
SD			6.76	7.07	8.75	0.03	0.00	0.83	1.70	NA

Pre-patrol urine samples not collected

MID EXPERIMENT (First phase - slow patrol - finished 3.42 hours after commencement)

NO	WEIGHT BEFORE RESUP (KG)	WEIGHT POST RESUP (KG)	WATER PRE-RESUP (L)	WATER POST RESUP (L)	WATER INTAKE TO OP (L)	URINE PROD TO OP (L)
S1	98.85	101.20	1.95	4.30	2.35	0.08
S2	98.25	100.85	1.70	4.30	2.60	0.10
S4	103.65	106.65	1.30	4.30	3.00	0.22
S5	103.95	106.85	1.40	4.30	2.90	0.60
S6	104.20	106.83	1.95	4.58	2.35	0.07
S7	91.90	94.10	2.35	4.55	1.95	0.09
S8	85.90	87.50	2.70	4.30	1.60	0.16
S9	110.30	111.70	2.90	4.30	1.40	0.00
S10	89.45	91.30	2.45	4.30	1.85	0.13
MEAN	98.49	100.78	2.08	4.36	2.22	0.16
SD	8.00	8.20	0.56	0.12	0.56	0.18

POST PATROL (Second phase consisted of 1.08 hour of rest and .55 hour of patrol/assault)

NO	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	FINAL WATER (L)	WATER INTAKE FROM OP (L)	MAG FINAL (KG)	POST PATROL URINE (L)	TOTAL WATER DRUNK (L)	TOTAL SWEAT PROD (L)#	TOTAL URINE PROD (L)#
S1	76.45	84.00	99.15	2.90	1.40	1.75	0.05	3.75	5.58	0.13
S2	71.95	78.65	98.85	3.90	0.40	1.60	0.04	3.00	4.62	0.14
S4	74.50	81.60	105.35	3.20	1.10	2.35	0.09	4.10	5.45	0.31
S5	85.35	90.25	104.60	2.35	1.95	1.15	0.36	4.85	2.80	0.96
S6	74.75	78.50	103.20	3.75	0.83	5.30	0.05	3.18	5.02	0.12
S7	67.45	71.20	89.35	3.30	1.25	2.00	0.18	3.20	4.13	0.27
S8	65.80	71.35	86.00	3.40	0.90	2.05	0.05	2.50	3.82	0.21
S9	83.45	90.05	109.40	2.80	1.50	1.65	0.13	2.90	6.88	0.13
S10	69.80	75.00	89.55	3.60	0.70	1.20	0.11	2.55	3.68	0.24
MEAN	74.39	80.07	98.38	3.24	1.11	2.12	0.12	3.34	4.66	0.28
SD	6.67	7.12	8.26	0.49	0.47	1.25	0.10	0.77	1.22	0.26

Hydration: Raw Data for HF1-HF4 (HRTA) (continued)

HF # 3, 8 FEB 98, RAW DATA
PRE-PATROL

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	NUDE WEIGHT (KG)	CLOTHE WEIGHT (KG)	PATROL ORDER (KG)	BREAK-FAST EATEN (KG)	INITIAL WATER (L)	WATER DRUNK PRE-PATROL (L)	MAG (INITIAL) (KG)	URINE PRE-PATROL (L)
1	CBCS	C	79.05	83.40	100.45	0.27	4.30	0.55	1.80	0.41
2	CBCS	C	73.65	78.25	99.45	0.27	4.30	0.80	2.40	0.23
3	CBA	C	69.60	73.95	97.80	0.27	4.30	0.30	5.50	0.00
4	DPCU	C	76.15	79.55	104.05	0.27	4.30	0.00	2.30	0.00
5	CBA	C	85.30	92.10	109.50	0.27	4.30	3.00	2.25	0.69
6	DPCU	ST	76.40	79.60	106.75	0.27	4.30	0.00	7.20	0.00
7	DPCU	C	67.85	71.20	90.55	0.27	4.30	0.50	2.50	0.36
8	DPCU	ST	67.35	70.55	86.90	0.27	4.80	0.55	2.50	0.15
9	DPCU	ST	87.20	90.90	112.85	0.27	4.35	0.35	2.25	0.12
10	DPCU	ST	70.85	74.10	89.50	0.27	4.45	0.00	2.10	0.00
MEAN			75.34	79.36	99.78	0.27	4.37	0.61	3.08	0.20
SD			6.92	7.56	8.78	0.00	0.16	0.88	1.78	0.23

HF# 3 MID EXPERIMENT (First phase - slow patrol - finished 3.20 hours after commencement of patrol)

NO	WEIGHT BEFORE RESUP (KG)	WEIGHT POST RESUP (KG)	WATER PRE-RESUP (L)	WATER POST RESUP (L)	WATER INTAKE TO OP (L)	URINE PROD TO OP (L)
1	98.55	100.50	2.35	4.30	1.95	0.00
2	98.00	99.85	2.45	4.30	1.85	0.00
3	95.95	97.95	2.30	4.30	2.00	0.21
4	102.50	103.50	3.30	4.30	1.00	0.24
5	107.35	111.05	0.60	4.30	3.70	0.26
6	104.30	106.80	2.10	4.60	2.20	0.12
7	88.55	90.15	2.70	4.30	1.60	0.08
8	85.05	86.40	3.35	4.70	1.45	0.07
9	109.15	111.00	2.75	4.60	1.60	0.06
10	88.80	89.70	3.15	4.05	1.30	0.11
MEAN	97.82	99.69	2.51	4.38	1.87	0.11
SD	8.28	8.78	0.80	0.20	0.74	0.09

POST PATROL (Second phase consisted of 1.0 hr of rest and 0.5 hr of patrol/assault)

NO	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER (KG)	FINAL WATER (KG)	WATER INTAKE FROM OP (KG)	MAG FINAL (KG)	POST PATROL URINE (L)	TOTAL WATER DRUNK (L)	TOTAL SWEAT PROD (L)	TOTAL URINE PROD (L)
1	78.00	83.60	98.90	2.70	1.60	1.75	0.15	3.55	4.31	0.56
2	72.95	78.75	98.05	2.95	1.35	1.75	0.05	3.20	3.89	0.28
3	67.35	73.65	94.20	3.25	1.05	1.95	0.02	3.05	5.35	0.23
4	74.80	78.65	103.25	3.10	1.20	2.30	0.09	2.20	3.49	0.33
5	85.90	93.60	108.00	1.55	2.75	1.50	0.37	6.45	4.81	1.31
6	75.00	78.90	103.35	3.50	1.10	5.10	0.06	3.30	4.79	0.18
7	66.30	70.50	88.70	3.50	0.80	1.85	0.03	2.40	3.75	0.47
8	67.05	70.80	84.85	2.90	1.80	1.95	0.04	3.25	3.56	0.26
9	84.80	90.60	109.15	2.85	1.75	2.00	0.03	3.35	5.82	0.21
10	70.80	74.75	88.60	1.65	2.40	1.00	0.13	3.70	3.78	0.24
MEAN	74.30	79.38	97.71	2.80	1.58	2.12	0.10	3.45	4.36	0.40
SD	6.98	7.84	8.45	0.68	0.62	1.10	0.11	1.16	0.80	0.34

Hydration: Raw data for HF1-HF4 (HRTA) (continued)

HF4, 9 FEB 98 - RAW DATA

PRE-PATROL

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER (KG)	BREAK-FAST EATEN (KG)	INITIAL WATER (L)	WATER DRUNK PRE-PATROL (L)	MAG (INITIAL) (KG)	URINE PRE-PATROL (L)
S1	DPCU	ST	79.00	82.05	98.50	0.50	4.30	0.60	1.75	0.00
S2	DPCU	ST	73.30	76.65	97.55	0.50	4.25	0.80	2.00	0.00
S3	DPCU	ST	68.85	72.15	93.30	0.50	4.80	0.00	5.05	0.00
S4	CBCS	C	75.10	79.55	103.60	0.50	4.30	0.00	1.75	0.00
S5	CBCS	C	85.50	90.25	106.55	0.50	4.30	3.00	1.80	0.37
S6	CBA	C	76.30	81.35	106.20	0.50	4.30	0.00	5.00	0.00
S7	CBA	C	66.85	72.55	91.60	0.50	4.30	0.40	2.05	0.00
S8	DPCU	C	67.35	70.30	86.05	0.50	4.30	0.60	2.10	0.00
S9	DPCU	C	86.60	90.35	111.10	0.50	4.30	0.55	2.05	0.00
S10	DPCU	C	71.30	74.35	89.95	0.50	4.30	0.75	1.85	0.00
MEAN			75.02	78.96	98.44	0.50	4.35	0.67	2.54	0.04
SD			7.01	7.16	8.25	0.00	0.16	0.88	1.32	0.12

MID EXPERIMENT (First phase - slow patrol - finished 3.33 hours after commencement of patrol)

NO	WEIGHT BEFORE RESUP	WEIGHT POST RESUP	WATER PRE-RESUP	WATER POST RESUP	WATER INTAKE TO OP	URINE PROD TO OP
S1	96.70	98.15	2.95	4.40	1.35	0.18
S2	95.90	98.20	2.00	4.30	2.25	0.36
S3	94.10	96.00	2.75	4.65	2.05	0.12
S4	101.70	103.85	2.15	4.30	2.15	0.19
S5	104.05	106.55	1.80	4.30	2.50	0.64
S6	103.80	107.00	1.10	4.30	3.20	0.12
S7	89.70	92.05	1.95	4.30	2.35	0.10
S8	84.75	85.85	3.20	4.30	1.10	0.18
S9	108.55	110.65	2.20	4.30	2.10	0.15
S10	89.05	90.25	3.10	4.30	1.20	0.12
MEAN	96.83	98.86	2.32	4.35	2.03	0.22
SD	7.66	8.08	0.67	0.11	0.65	0.17

POST PATROL (Second phase consisted of 0.73 hr of rest and 0.80 hr of patrol/assault)

NO	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER (KG)	FINAL WATER (L)	WATER INTAKE FROM OP (L)	MAG FINAL (KG)	POST PATROL URINE (L)	TOTAL WATER DRUNK (L)	TOTAL SWEAT PROD (L)	TOTAL URINE PROD (L)
S1	77.35	81.55	96.90	3.45	0.95	1.40	0.15	2.30	4.12	0.33
S2	73.45	77.35	94.80	1.55	2.75	1.25	0.06	5.00	4.93	0.42
S3	67.10	70.95	92.05	3.10	1.55	2.55	0.05	3.60	5.68	0.17
S4	74.00	78.95	102.45	3.40	0.90	1.75	0.05	3.05	4.41	0.24
S5	84.05	90.35	104.30	2.40	1.90	1.25	0.42	4.40	4.92	1.43
S6	74.95	80.90	102.90	3.80	0.50	2.55	0.06	3.70	5.37	0.18
S7	65.45	72.60	90.15	3.40	0.90	1.40	0.04	3.25	5.01	0.14
S8	66.80	70.35	84.60	3.00	1.30	1.80	0.06	3.40	4.21	0.24
S9	83.60	88.30	108.40	3.80	0.50	1.70	0.06	1.70	4.99	0.21
S10	70.65	74.25	88.25	3.50	0.80	0.85	0.22	2.87	3.68	0.34
MEAN	73.74	78.56	96.48	3.14	1.21	1.65	0.12	3.33	4.73	0.37
SD	6.57	6.91	7.83	0.69	0.70	0.55	0.12	0.95	0.61	0.38

Hydration: Raw data for HF5&HF6 (LCBS)

1. HF5 RAW DATA, LCBS

PRE-PATROL

NO	UNIFORM	WATER DELIVERY (Canteen or SportTank)	NUDE WEIGHT (KG)	CLOTHE WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	WATER CARRIED (L)	WT OF B'FAST (KG)	PRE-PATROL URINE (L)
S1	DPCU	ST + 2C	80.35	83.30	100.55	4.05	0.40	0.20
S2	DPCU	ST + 2C	73.00	75.85	97.20	4.15	0.40	0.00
S3	DPCU	2 C	69.40	72.50	96.00	2.10	0.40	0.15
S4	DPCU	ST + 2C	75.55	79.15	94.65	4.10	0.40	0.00
S5	DPCU	ST + 2C	86.85	90.05	105.15	4.35	0.40	0.95
S6	CBA	ST + 2C	77.50	82.35	108.00	4.20	0.40	0.20
S7	CBA	ST + 2C	68.25	73.70	91.05	4.30	0.40	0.20
S8	CBA	ST + 2C	67.34	73.05	88.55	4.45	0.40	0.00
S9	CBA	2C + 2L	88.90	95.85	112.70	4.20	0.40	0.15
MEAN			76.35	80.64	99.32	3.99	0.40	0.21
SD			7.84	8.12	8.00	0.72	0.00	0.29

NOTE 1 - Soldier 10 withdrew from the study before HF#5 commenced
NOTE 2 -Pre-patrol water intake was not obtained for this study
NOTE 3 - Magazines were not taken on this patrol, soldiers carried extra water instead

Post-Patrol

NO	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	WATER LEFT (L)	POST PATROL URINE (L)
S1	77.60	82.85	99.35	3.60	0.20
S2	72.80	77.00	96.10	2.35	0.20
S3	67.70	72.75	94.60	0.85	0.10
S4	75.25	79.80	93.90	0.60	0.40
S5	84.50	89.25	102.60	2.80	0.45
S6	74.70	82.45	106.60	3.00	0.15
S7	67.30	74.65	89.95	2.30	0.10
S8	66.65	73.65	87.30	2.55	0.15
S9	86.25	95.55	110.50	2.20	0.20
Mean	74.75	80.88	97.88	2.25	0.22
SD	7.16	7.62	7.62	0.97	0.13

Hydration: Raw Data, HF5 & HF6 (LCBS) (continued)

HF6 RAW DATA, LCBS

PRE-PATROL

NO	UNIFORM	WATER DELIVERY	NUDE WEIGHT (KG)	LOTHE WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	WATER CARRIED (L)	WT OF B'FAST (KG)	PRE-PATROL URINE (L)	WATER DRUNK PRE-PATROL (L)
S1	CBA	ST + 3C	80.35	86.30	102.50	5.25	0.54	0.00	0.00
S2	CBA	ST + 3C	74.30	79.95	99.40	5.10	0.38	0.00	0.00
S3	CBA	3C	68.70	74.15	95.63	3.15	0.54	0.00	0.00
S4	CBA	ST + 2C	74.40	80.15	94.80	3.75	0.54	0.00	0.00
S5	CBA	ST + 3C	84.90	91.00	106.45	5.35	0.75	0.45	0.00
S6	DPCU	ST + 3C	75.75	78.80	101.65	5.35	0.38	0.00	0.00
S7	DPCU	ST + 3C	68.30	71.60	87.80	5.15	0.38	0.00	0.00
S8	DPCU	ST + 3C	68.00	70.95	85.80	5.35	0.38	0.10	0.00
S9	DPCU	2C + 2L	88.40	92.00	109.00	4.90	0.54	0.00	0.30
MEAN			75.90	80.54	98.11	4.82	0.49	0.06	0.03
SD			7.36	7.83	7.88	0.80	0.13	0.15	0.10

NOTE - Magazines were not taken on this patrol, soldiers carried extra water instead

POST PATROL

NO	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	WATER LEFT (L)	POST PATROL URINE (L)
S1	79.45	86.75	100.95	3.25	0.20
S2	72.90	80.50	97.45	1.75	0.10
S3	67.40	75.65	93.75	0.45	0.05
S4	73.65	78.05	96.65	2.85	0.00
S5	83.85	92.45	104.75	2.60	0.30
S6	74.55	79.25	101.85	3.65	0.10
S7	67.60	72.25	86.55	3.80	0.15
S8	67.05	71.10	84.80	4.25	0.20
S9	86.80	92.20	107.10	2.80	0.25
MEAN	74.81	80.91	97.09	2.82	0.15
SD	7.24	7.94	7.67	1.16	0.10

Appendix 9: Hydration: Summarised Data

Hydration: Summarised Data for HF1-HF4 (HRTA)

HF1, HRTA, 6 FEB 98 : SUMMARY OF WATER INTAKE, URINE PRODUCTION AND SWEAT RATES

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	WATER INTAKE TO OP (L)	RATE OF INTAKE TO OP (L/HR)	INTAKE FROM OP (L)	RATE OF INTAKE FROM OP (L/HR)	TOTAL WATER INTAKE (L)	RATE OF TOTAL INTAKE (L/HR)
S1	DPCU	C	1.85	0.43	1.70	1.08	3.55	0.61
S2	DPCU	C	3.65	0.85	1.40	0.89	5.05	0.86
S4	DPCU	ST	2.45	0.57	1.70	1.08	4.15	0.71
S5	DPCU	ST	2.30	0.54	1.70	1.08	4.00	0.68
S6	CBCS	C	2.95	0.69	0.75	0.48	3.70	0.63
S7	CBCS	C	3.10	0.73	1.10	0.70	4.20	0.72
S8	CBA	C	2.30	0.54	1.45	0.92	3.75	0.64
S9	CBA	C	3.65	0.85	1.55	0.99	5.20	0.89
S10	CBA	C	1.60	0.37	0.00	0.00	1.60	0.27
MEAN			2.65	0.62	1.26	0.80	3.91	0.67
SD			0.73	0.17	0.57	0.36	1.04	0.18

NO	TOTAL WEIGHT LOSS (KG)	RATE OF WEIGHT LOSS (KG/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	ON-EVA SWEAT (L)	NON-EVAP SWEAT RATE (L/HR)	EVAP SWEAT (L)	EVAP SWEAT RATE (L/HR)
S1	2.40	0.41	0.33	0.06	5.62	0.96	0.95	0.16	4.67	0.80
S2	0.85	0.15	0.18	0.03	5.72	0.98	0.65	0.11	5.07	0.87
S4	1.45	0.25	0.31	0.05	5.29	0.91	0.55	0.09	4.74	0.81
S5	1.40	0.24	0.78	0.13	4.62	0.79	0.95	0.16	3.67	0.63
S6	3.00	0.51	0.16	0.03	6.54	1.12	1.00	0.17	5.54	0.95
S7	1.65	0.28	0.37	0.06	5.48	0.94	1.25	0.21	4.23	0.72
S8	1.75	0.30	0.18	0.03	5.32	0.91	0.30	0.05	5.02	0.86
S9	4.80	0.82	0.21	0.04	9.79	1.68	0.75	0.13	9.04	1.55
S10	2.20	0.38	0.20	0.03	3.60	0.62	0.70	0.12	2.90	0.50
MEA	2.17	0.37	0.30	0.05	5.78	0.99	0.79	0.14	4.99	0.85
SD	1.17	0.20	0.19	0.03	1.71	0.29	0.28	0.05	1.72	0.29

TIME OF INITIAL PATROL (TO OP)	4.27
TIME SPENT AT REST AT OP	0.95
TIME FOR PATROL/ASSAULT (FROM OP TO FINISH)	0.62
TIME OF SECOND PHASE (REST AT OP + ASSAULT)	1.57
TOTAL TIME OF ACTIVITY	5.84

Hydration: Summarised Data for HF1-HF4 (HRTA) (continued)

HF2, HRTA, 7 FEB 98 : SUMMARY OF WATER INTAKE, URINE PRODUCTION AND SWEAT RATES

NO	UNIFORM	DELIVERY (Canteen or Sport Tank)	WATER INTAKE TO OP (L)	RATE OF INTAKE TO OP (L/HR)	WATER INTAKE FROM OP (L)	RATE OF INTAKE FROM OP (L/HR)	TOTAL WATER INTAKE (L)	RATE OF TOTAL INTAKE (L/HR)
S1	CBA	C	2.35	0.69	1.40	0.86	3.75	0.74
S2	CBA	C	2.60	0.76	0.40	0.25	3.00	0.59
S4	CBA	C	3.00	0.88	1.10	0.67	4.10	0.81
S5	DPCU	C	2.90	0.85	1.95	1.20	4.85	0.96
S6	DPCU	ST	2.35	0.69	0.83	0.51	3.18	0.63
S7	DPCU	ST	1.95	0.57	1.25	0.77	3.20	0.63
S8	CBCS	C	1.60	0.47	0.90	0.55	2.50	0.50
S9	CBCS	C	1.40	0.41	1.50	0.92	2.90	0.57
S10	CBCS	C	1.85	0.54	0.70	0.43	2.55	0.50
MEAN			2.22	0.65	1.11	0.68	3.34	0.66
SD			0.56	0.16	0.47	0.29	0.77	0.15

NO	TOTAL WEIGHT LOSS (KG)	RATE OF WEIGHT LOSS (KG/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	TOTAL NON-EVAP SWEAT (L)	NON-EVAP SWEAT RATE (L/HR)	TOTAL EVAP SWEAT (L)	EVAP SWEAT RATE (L/HR)
S1	1.55	0.31	0.13	0.03	5.58	1.10	1.65	0.33	3.93	0.78
S2#	1.35	0.27	0.14	0.03	4.62	0.91	1.13	0.22	3.49	0.69
S4	1.25	0.25	0.31	0.06	5.45	1.08	1.05	0.21	4.40	0.87
S5	-1.50	-0.30	0.96	0.19	2.80	0.55	1.00	0.20	1.80	0.36
S6	1.55	0.31	0.12	0.02	5.02	0.99	0.75	0.15	4.27	0.85
S7	0.85	0.17	0.27	0.05	4.13	0.82	0.75	0.15	3.38	0.67
S8	1.15	0.23	0.21	0.04	3.82	0.76	1.20	0.24	2.62	0.52
S9	3.70	0.73	0.13	0.03	6.88	1.36	1.70	0.34	5.18	1.03
S10	0.90	0.18	0.24	0.05	3.68	0.73	0.90	0.18	2.78	0.55
MEA	1.20	0.24	0.28	0.06	4.66	0.92	1.13	0.22	3.54	0.70
SD	1.32	0.26	0.26	0.05	1.22	0.24	0.35	0.07	1.04	0.21

NOTE: An anomalous result was obtained for non-evaporative sweat (negative value) for subject 2. The result reported is the mean for the other 8 subjects.

TIME OF INITIAL PATROL (TO OP)	3.42
TIME SPENT AT REST AT OP	1.08

Hydration: Summarised Data for HF1-HF4 (HRTA) (continued)

HF3, HRTA, 8 FEB 98: SUMMARY OF WATER INTAKE, URINE PRODUCTION AND SWEAT RATES

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	WATER INTAKE TO OP (L)	RATE OF INTAKE TO OP (L/HR)	WATER INTAKE FROM OP (L)	RATE OF INTAKE FROM OP (L/HR)	TOTAL WATER INTAKE (L)	RATE OF TOTAL INTAKE (L/HR)
S1	CBCS	C	1.95	0.61	1.60	1.07	3.55	0.76
S2	CBCS	C	1.85	0.58	1.35	0.90	3.20	0.68
S3	CBA	C	2.00	0.63	1.05	0.70	3.05	0.65
S4	DPCU	C	1.00	0.31	1.20	0.80	2.20	0.47
S5	CBA	C	3.70	1.16	2.75	1.83	6.45	1.37
S6	DPCU	ST	2.20	0.69	1.10	0.73	3.30	0.70
S7	DPCU	C	1.60	0.50	0.80	0.53	2.40	0.51
S8	DPCU	ST	1.45	0.45	1.80	1.20	3.25	0.69
S9	DPCU	ST	1.60	0.50	1.75	1.17	3.35	0.71
S10	DPCU	ST	1.30	0.41	2.40	1.60	3.70	0.79
MEAN			1.87	0.58	1.58	1.05	3.45	0.73
SD			0.74	0.23	0.62	0.41	1.16	0.25

NO	TOTAL WEIGHT LOSS (KG)	RATE OF WEIGHT LOSS (KG/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	NON-EVAP SWEAT (L)	NON-EVAP SWEAT RATE (L/HR)	EVAP SWEAT (L)	EVAP SWEAT RATE (L/HR)
S1	1.05	0.22	0.56	0.12	4.31	0.92	1.25	0.27	3.06	0.65
S2	0.70	0.15	0.28	0.06	3.89	0.83	1.20	0.26	2.69	0.57
S3	2.25	0.48	0.23	0.05	5.35	1.14	1.95	0.41	3.40	0.72
S4	1.35	0.29	0.33	0.07	3.49	0.74	0.45	0.10	3.04	0.65
S5	-0.60	-0.13	1.31	0.28	4.81	1.02	0.90	0.19	3.91	0.83
S6	1.40	0.30	0.18	0.04	4.79	1.02	0.70	0.15	4.09	0.87
S7	1.55	0.33	0.47	0.10	3.75	0.80	0.85	0.18	2.90	0.62
S8	0.30	0.06	0.26	0.05	3.56	0.76	0.55	0.12	3.01	0.64
S9	2.40	0.51	0.21	0.04	5.82	1.24	2.10	0.45	3.72	0.79
S10	0.05	0.01	0.24	0.05	3.78	0.80	0.70	0.15	3.08	0.66
MEA	1.05	0.22	0.40	0.09	4.36	0.93	1.07	0.23	3.29	0.70
SD	0.95	0.20	0.34	0.07	0.80	0.17	0.57	0.12	0.47	0.10

TIME OF INITIAL PATROL (TO OP)	3.2	hr
TIME SPENT AT REST AT OP	1.0	hr
TIME FOR PATROL/ASSAULT (FROM OP TO FINISH)	0.5	hr

Hydration: Summarised Data for HF1-HF4 (HRTA) (continued)

HF4, 9 FEB 98: SUMMARY OF WATER INTAKE AND SWEAT RATES

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	WATER INTAKE TO OP (L)	RATE OF INTAKE TO OP (L/HR)	WATER INTAKE FROM OP (L)	RATE OF INTAKE FROM OP (L/HR)	TOTAL WATER INTAKE (L)	RATE OF TOTAL INTAKE (L/HR)
S1	DPCU	ST	1.35	0.41	0.95	1.30	2.30	0.47
S2	DPCU	ST	2.25	0.68	2.75	3.77	5.00	1.03
S3	DPCU	ST	2.05	0.62	1.55	2.12	3.60	0.74
S4	CBCS	C	2.15	0.65	0.90	1.23	3.05	0.63
S5	CBCS	C	2.50	0.75	1.90	2.60	4.40	0.91
S6	CBA	C	3.20	0.96	0.50	0.68	3.70	0.76
S7	CBA	C	2.35	0.71	0.90	1.23	3.25	0.67
S8	DPCU	C	1.10	0.33	1.30	1.78	3.40	0.70
S9	DPCU	C	2.10	0.63	0.50	0.68	1.70	0.35
S10	DPCU	C	1.20	0.36	0.80	1.10	2.87	0.59
MEAN			2.03	0.61	1.21	1.65	3.33	0.68
SD			0.65	0.19	0.70	0.96	0.95	0.20

NO	TOTAL WEIGHT LOSS (KG)	RATE OF WEIGHT LOSS (KG/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	NON-EVAP SWEAT PROD (L)	NON-EVAP SWEAT RATE (L/HR)	EVAP SWEAT (L)	EVAP SWEAT RATE (L/HR)
S1	1.65	0.34	0.33	0.07	4.12	0.85	1.15	0.24	3.57	0.73
S2	-0.15	-0.03	0.42	0.09	4.93	1.01	0.55	0.11	4.38	0.90
S3	1.75	0.36	0.17	0.03	5.68	1.17	0.55	0.11	5.18	1.07
S4	1.10	0.23	0.24	0.05	4.41	0.91	0.50	0.10	2.86	0.59
S5	1.45	0.30	1.43	0.29	4.92	1.01	1.55	0.32	4.02	0.83
S6	1.35	0.28	0.18	0.04	5.37	1.10	0.90	0.19	3.92	0.81
S7	1.40	0.29	0.14	0.03	5.01	1.03	1.45	0.30	4.41	0.91
S8	0.55	0.11	0.24	0.05	4.21	0.87	0.60	0.12	3.26	0.67
S9	3.00	0.62	0.21	0.04	4.99	1.03	0.95	0.20	4.44	0.91
S10	0.65	0.13	0.34	0.07	3.68	0.76	0.55	0.11	2.80	0.58
MEAN	1.28	0.26	0.37	0.08	4.73	0.97	0.87	0.18	3.88	0.80
SD	0.84	0.17	0.38	0.08	0.61	0.13	0.39	0.08	0.76	0.16

TIME OF INITIAL PATROL (TO OP)	3.33	hr
TIME SPENT AT REST AT OP	0.73	hr
TIME FOR PATROL/ASSAULT (FROM OP TO FINISH)	0.80	hr

Hydration: Summarised data, HF5&6 (LCBS).

1. HF5 SUMMARY OF HYDRATION

NO	UNIFORM	WATER DELIVERY (Canteen or SportTank)	INITIAL NUDE (KG)	FINAL NUDE (KG)	WEIGHT LOSS (KG)	WATER TAKEN (L)	WATER LEFT (L)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)
S1	DPCU	ST + 2C	80.35	77.60	2.75	4.05	3.60	0.45	0.22
S2	DPCU	ST + 2C	73.00	72.80	0.20	4.15	2.35	1.80	0.87
S3	DPCU	2 C	69.40	67.70	1.70	2.10	0.85	1.25	0.60
S4	DPCU	ST + 2C	75.55	75.25	0.30	4.10	0.60	3.50	1.68
S5	DPCU	ST + 2C	86.85	84.50	2.35	4.35	2.80	1.55	0.75
S6	CBA	ST + 2C	77.50	74.70	2.80	4.20	3.00	1.20	0.58
S7	CBA	ST + 2C	68.25	67.30	0.95	4.30	2.30	2.00	0.96
S8	CBA	ST + 2C	67.34	66.65	0.69	4.45	2.55	1.90	0.91
S9	CBA	2C + 2L	88.90	86.25	2.65	4.20	2.20	2.00	0.96
MEAN			76.35	74.75	1.60	3.99	2.25	1.74	0.84
SD			7.84	7.16	1.08	0.72	0.97	0.83	0.40

NO	TOTAL URINE (L)	RATE OF URINE PROD'N (L/HR)	TOTAL SWEAT (L)	TOTAL SWEAT RATE (L/HR)	NON-EVAP SWEAT (L)	NON-EVA SWEAT RATE (L/HR)	EVAP SWEAT (L)	EVAP SWEAT RATE (L/HR)
S1	0.40	0.19	2.80	1.35	2.30	1.11	0.50	0.24
S2	0.20	0.10	1.80	0.87	1.35	0.65	0.45	0.22
S3	0.25	0.12	2.70	1.30	1.95	0.94	0.75	0.36
S4	0.40	0.19	3.40	1.63	0.95	0.46	2.45	1.18
S5	1.40	0.67	2.50	1.20	1.55	0.75	0.95	0.46
S6	0.35	0.17	3.65	1.75	2.90	1.39	0.75	0.36
S7	0.30	0.14	2.65	1.27	1.90	0.91	0.75	0.36
S8	0.15	0.07	2.44	1.17	1.29	0.62	1.15	0.55
S9	0.35	0.17	4.30	2.07	2.35	1.13	1.95	0.94
MEAN	0.42	0.20	2.92	1.40	1.84	0.88	1.08	0.52
SD	0.38	0.18	0.75	0.36	0.62	0.30	0.68	0.33

Hydration: Summarised Data, HF5 & HF6 (LCBS) (continued)

2. HF6 SUMMARY OF HYDRATION

NO	UNIFORM	WATER DELIVERY (Canteen or SportTank)	INITIAL NUDE (KG)	FINAL NUDE (KG)	WEIGHT LOSS (KG)	WATER TAKEN (L)	WATER LEFT (L)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)
S1	CBA	ST + 3C	80.35	79.45	0.90	5.25	3.25	2.00	1.14
S2	CBA	ST + 3C	74.30	72.90	1.40	5.10	1.75	3.35	1.91
S3	CBA	3C	68.70	67.40	1.30	3.15	0.45	2.70	1.54
S4	CBA	ST + 2C	74.40	73.65	0.75	3.75	2.85	0.90	0.51
S5	CBA	ST + 3C	84.90	83.85	1.05	5.35	2.60	2.75	1.57
S6	DPCU	ST + 3C	75.75	74.55	1.20	5.35	3.65	1.70	0.97
S7	DPCU	ST + 3C	68.30	67.60	0.70	5.15	3.80	1.35	0.77
S8	DPCU	ST + 3C	68.00	67.05	0.95	5.35	4.25	1.10	0.63
S9	DPCU	2C + 2L	88.40	86.80	1.60	4.90	2.80	2.10	1.20
MEAN			75.90	74.81	1.09	4.82	2.82	1.99	1.14
SD			7.36	7.24	0.30	0.80	1.16	0.82	0.47

NO	TOTAL URINE PROD (L)	RATE OF URINE PRO (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	NON-EVAP SWEAT (L)	NON-EVAP SWEAT RATE (L)	EVAP SWEAT (L)	EVAP SWEAT RATE (L/HR)
S1	0.20	0.11	2.70	1.54	1.35	0.77	1.35	0.77
S2	0.10	0.06	4.65	2.66	1.95	1.11	2.70	1.54
S3	0.05	0.03	3.95	2.26	2.80	1.60	1.15	0.66
S4#	0.00	0.00	1.65	0.94	1.81	1.04	1.22	0.70
S5	0.75	0.43	3.05	1.74	2.50	1.43	0.55	0.31
S6	0.10	0.06	2.80	1.60	1.65	0.94	1.15	0.66
S7	0.15	0.09	1.90	1.09	1.35	0.77	0.55	0.31
S8	0.30	0.17	1.75	1.00	1.10	0.63	0.65	0.37
S9	0.25	0.14	3.45	1.97	1.80	1.03	1.65	0.94
MEAN	0.21	0.12	2.88	1.64	1.81	1.04	1.22	0.70
SD	0.22	0.13	1.03	0.59	0.55	0.31	0.67	0.38

Time of Patrol 1.75 hours

NOTE: The evaporative sweat rate for soldier 4 was anomalous (negative result).
The rate reported is the mean of the rates for the other eight subjects.

Hydration: Summarised Data:
Comparison of CBA and DPCU (HF1-HF4, HRTA)

1. DPCU PLUS WATER BOTTLE

NO	CHANGE IN WEIGHT (KG)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)	TOTAL SWEAT PROD (L)	SWEAT RATE (L/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	FINAL URINE SODIUM (mmol/L)	FINAL URINE SG
S1	2.40	3.55	0.61	5.62	0.96	0.33	0.06	82	1.028
S2	0.85	5.05	0.86	5.72	0.98	0.18	0.03	15	1.026
S4	1.35	2.20	0.47	5.29	1.13	0.33	0.07	131	1.021
S5	-1.50	1.95	1.20	4.62	0.98	0.96	0.19	0	1.004
S7	1.55	2.40	0.51	6.54	1.39	0.47	0.10	0	1.029
S8	0.55	3.40	0.70	5.48	1.13	0.24	0.05	51	1.027
S9	3.00	1.70	0.35	5.32	1.09	0.21	0.04	0	1.027
S10	0.65	2.87	0.59	9.79	2.01	0.34	0.07	32	1.020
MEAN	1.11	2.89	0.66	6.05	1.21	0.38	0.08	38.88	1.023
SD	1.36	1.09	0.27	1.60	0.35	0.25	0.05	47.28	0.008

2. CBA PLUS WATER BOTTLE

NO	CHANGE IN WEIGHT (KG)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)	TOTAL SWEAT PROD (L)	SWEAT RATE (L/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	FINAL URINE SODIUM (mmol/L)	FINAL URINE SG
S1	1.55	1.40	0.86	5.58	1.10	0.13	0.03	40	1.026
S2	1.35	0.40	0.25	4.62	0.91	0.14	0.03	0	1.030
S4	1.25	1.10	0.67	5.45	1.08	0.31	0.06	0	1.025
S5	-0.60	6.45	1.37	4.81	1.02	1.31	0.28	NA	NA
S7	1.40	3.25	0.67	5.01	1.03	0.14	0.03	0	1.029
S8	1.75	3.75	0.64	5.32	0.91	0.18	0.03	NA	NA
S9	4.80	5.20	0.89	9.79	1.68	0.21	0.04	37	1.030
S10	2.20	1.60	0.27	3.60	0.62	0.20	0.03	39	1.032
MEAN	1.71	2.89	0.70	5.52	1.04	0.33	0.07	19.33	1.029
SD	1.49	2.14	0.36	1.83	0.30	0.40	0.09	21.20	0.003

DIFFERENCE BETWEEN DPCU AND CBA (POSTIVE NUMBER IMPLIES CBA RESULT WAS HIGHER)

NO	CHANGE IN WEIGHT (KG)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)	TOTAL SWEAT PROD (L)	SWEAT RATE (L/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	FINAL URINE SODIUM (mmol/L)	FINAL URINE SG
S1	-0.85	-2.15	0.25	-0.04	0.14	-0.20	-0.03	-42.00	-0.002
S2	0.50	-4.65	-0.62	-1.10	-0.06	-0.04	0.00	-15.00	0.004
S4	-0.10	-1.10	0.21	0.16	-0.05	-0.02	-0.01	-131.00	0.004
S5	0.90	4.50	0.18	0.19	0.04	0.35	0.09	NA	NA
S7	-0.15	0.85	0.16	-1.53	-0.36	-0.33	-0.07	0.00	0.000
S8	1.20	0.35	-0.06	-0.16	-0.22	-0.06	-0.02	NA	NA
S9	1.80	3.50	0.54	4.47	0.58	0.00	-0.01	37.00	0.003
S10	1.55	-1.27	-0.32	-6.19	-1.40	-0.14	-0.04	7.00	0.012
MEAN	0.61	0.00	0.04	-0.53	-0.17	-0.05	-0.01	-24.00	0.004
SD	0.92	2.99	0.36	2.92	0.57	0.20	0.05	58.50	0.005
STUDENT TTEST	0.226	0.499	0.376	0.313	0.220	0.230	0.264	0.181	0.067

Hydration: Summarised Data:
Effects of CBA versus DPCU (HF5 & HF6, LCBS)

DPCU Rates

NO	Weight Change (kg/hr)	Water Intake (kg/hr)	Total Sweat (L/hr)	Non Evap. sweat (L/hr)	Evap. Sweat (L/hr)	Urine Production (L/hr)
1	1.32	0.22	1.35	1.11	0.24	0.19
2	0.10	0.87	0.87	0.65	0.22	0.10
3	0.82	0.60	1.30	0.94	0.36	0.12
4	0.14	1.68	1.63	0.46	1.18	0.19
5	1.13	0.75	1.20	0.75	0.46	0.67
6	0.69	0.97	1.60	0.94	0.66	0.06
7	0.4	0.77	1.09	0.77	0.31	0.09
8	0.54	0.63	1.00	0.63	0.37	0.17
9	0.91	1.20	1.97	1.03	0.94	0.14
Mean	0.67	0.85	1.33	0.81	0.53	0.19
SD	0.42	0.41	0.35	0.21	0.33	0.19

CBA Rates

NO	Weight Change (kg/hr)	Water Intake (kg/hr)	Total Sweat (L/hr)	Non Evap. sweat (L/hr)	Evap. Sweat (L/hr)	Urine Production (L/hr)
1	0.51	0.58	1.75	1.39	0.36	0.17
2	0.80	0.96	1.27	0.91	0.36	0.14
3	0.74	0.91	1.17	0.62	0.55	0.07
4	0.43	0.96	2.07	1.13	0.94	0.17
5	0.60	1.14	1.54	0.77	0.77	0.11
6	1.35	1.91	2.66	1.11	1.54	0.06
7	0.46	1.54	2.26	1.60	0.66	0.03
8	0.33	0.51	0.94	1.04	0.70	0.00
9	1.27	1.57	1.74	1.43	0.31	0.43
Mean	0.72	1.12	1.71	1.11	0.69	0.13
SD	0.37	0.47	0.55	0.32	0.38	0.13

DIFFERENCE BETWEEN DPCU AND CBA (POSTIVE NUMBER IMPLIES CBA RESULT WAS HIGHER)

NO	**CHANGE IN WEIGHT (KG)**	**RATE OF WATER INTAKE (L/hr)**	**TOTAL SWEAT RATE (L/hr)**	**NON-EVAP SWEAT RATE (L/hr)**	**EVAP SWEAT RATE (L/hr)**	**TOTAL URINE PROD (L)**
S1	-0.81	0.36	0.41	0.29	0.12	-0.02
S2	0.70	0.10	0.41	0.26	0.14	0.05
S4	-0.08	0.31	-0.13	-0.32	0.19	-0.05
S5	0.29	-0.72	0.43	0.67	-0.24	-0.02
S7	-0.53	0.40	0.34	0.03	0.31	-0.56
S8	0.66	0.94	1.06	0.17	0.89	0.00
S9	0.06	0.77	1.17	0.83	0.34	-0.06
S10	-0.21	-0.11	-0.06	0.41	0.32	-0.17
MEAN	0.01	0.26	0.45	0.29	0.26	-0.10
SD	0.53	0.52	0.46	0.36	0.31	0.19
Prob.	0.31	0.07	**0.02**	**0.01**	0.14	0.22

Hydration: Summarised Data:
Comparison of CBCS and DPCU (HF1-HF4, HRTA)

1. DPCU PLUS WATER BOTTLE

NO	CHANGE IN WEIGHT (KG)	RATE OF CHANGE IN WT (KG/HR)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	EVAP SWEAT RATE (L/HR)	NON-EVAP SWEAT RATE (L/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	FINAL URINE SODIUM (mmol/L)	FINAL URINE SG
S1	2.40	0.41	3.55	0.61	5.62	0.96	0.80	0.16	0.33	0.06	82	1.028
S2	0.85	0.15	5.05	0.86	5.72	0.98	0.87	0.11	0.18	0.03	15	1.026
S4	1.35	0.29	2.20	0.47	3.49	0.74	0.65	0.10	0.33	0.07	131	1.021
S5	-1.50	-0.30	4.85	0.96	2.80	0.55	0.36	0.20	0.96	0.19	0	1.004
S7	1.55	0.33	2.40	0.51	3.75	0.80	0.62	0.18	0.47	0.10	0	1.029
S8	0.55	0.12	3.40	0.70	4.21	0.87	0.67	0.12	0.24	0.05	51	1.027
S9	3.00	0.63	1.70	0.35	4.99	1.03	0.91	0.20	0.21	0.04	0	1.027
S10	0.65	0.14	2.87	0.59	3.68	0.76	0.58	0.11	0.34	0.07	32	1.020
MEA	1.11	0.22	3.25	0.63	4.28	0.84	0.681	0.148	0.38	0.08	38.88	1.023
SD	1.36	0.27	1.21	0.20	1.06	0.16	0.179	0.041	0.25	0.05	47.28	0.008

2. CBCS PLUS WATER BOTTLE

NO	CHANGE IN WEIGHT (KG)	RATE OF CHANGE IN WT (KG/HR)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	EVAP SWEAT RATE (L/HR)	NON-EVAP SWEAT RATE (L/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	FINAL URINE SODIUM (mmol/L)	FINAL URINE SG
S1	1.05	0.22	3.55	0.76	4.31	0.92	0.65	0.27	0.56	0.12	0	1.027
S2	0.70	0.15	3.20	0.68	3.89	0.83	0.57	0.26	0.28	0.06	131	1.021
S4	1.10	0.23	3.05	0.63	4.41	0.91	0.59	0.10	0.24	0.05	92	1.030
S5	1.45	0.31	4.40	0.91	4.92	1.01	0.83	0.32	1.43	0.29	15	1.005
S7	1.65	0.28	4.20	0.72	5.48	0.94	0.72	0.21	0.37	0.06	76	1.026
S8	1.15	0.23	2.50	0.50	3.82	0.76	0.52	0.24	0.21	0.04	23	1.025
S9	3.70	0.73	2.90	0.57	6.88	1.36	1.03	0.34	0.13	0.03	NA	NA
S10	0.90	0.18	2.55	0.50	3.68	0.73	0.55	0.18	0.24	0.05	22	1.021
MEA	1.46	0.29	3.29	0.66	4.67	0.93	0.682	0.239	0.43	0.09	51.29	1.022
SD	0.95	0.19	0.71	0.14	1.08	0.20	0.172	0.075	0.42	0.09	48.70	0.008

DIFFERENCE BETWEEN DPCU AND CBCS (POSTIVE NUMBER IMPLIES CBCS RESULT WAS HIGHER)

NO	CHANGE IN WEIGHT (KG)	RATE OF CHANGE IN WT (KG/HR)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	EVAP SWEAT RATE (L/HR)	NON-EVAP SWEAT RATE (L/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	FINAL URINE SODIUM (mmol/L)	FINAL URINE SG
S1	-1.35	-0.19	0.00	0.15	-1.31	-0.05	-0.15	0.10	0.23	0.06	-82.00	0.00
S2	-0.15	0.00	-1.85	-0.18	-1.83	-0.15	-0.30	0.14	0.10	0.03	116.00	-0.01
S4	-0.25	-0.05	0.85	0.16	0.92	0.16	-0.06	0.01	-0.09	-0.02	-39.00	0.01
S5	2.95	0.60	-0.45	-0.06	2.12	0.46	0.47	0.12	0.47	0.10	15.00	0.00
S7	0.10	-0.05	1.80	0.21	1.73	0.14	0.11	0.03	-0.10	-0.04	76.00	0.00
S8	0.60	0.11	-0.90	-0.20	-0.39	-0.11	-0.15	0.11	-0.03	-0.01	-28.00	0.00
S9	0.70	0.10	1.20	0.22	1.89	0.34	0.11	0.14	-0.08	-0.02	NA	NA
S10	0.25	0.04	-0.32	-0.09	0.00	-0.03	-0.03	0.07	-0.10	-0.02	-10.00	0.00
MEA	0.36	0.07	0.04	0.03	0.39	0.10	0.001	0.091	0.05	0.01	6.86	0.000
SD	1.23	0.24	1.19	0.18	1.51	0.22	0.234	0.051	0.21	0.05	68.63	0.005
PRO Ttest	0.219	0.211	0.462	0.344	0.244	0.129	0.495	0.001	0.256	0.268	0.400	0.500

DISTRIBUTION LIST

A Methodology for Measuring the Physiological Strain of Enhanced Soldiers: The 1998 Soldier Combat System Enhancement Study

Denys Amos, James D. Cotter, Wai-Man Lau and Christopher Forbes-Ewan

AUSTRALIA

DEFENCE ORGANISATION

Task Sponsor DGLD and DGDHS

S&T Program

Chief Defence Scientist
FAS Science Policy
AS Science Corporate Management
} shared copy
Director General Science Policy Development
Counsellor Defence Science, London (Doc Data Sheet)
Counsellor Defence Science, Washington (Doc Data Sheet)
Scientific Adviser to MRDC Thailand (Doc Data Sheet)
Director General Scientific Advisers and Trials/Scientific Adviser Policy and Command (shared copy)
Navy Scientific Adviser (Doc Data Sheet and distribution list only)
Scientific Adviser - Army
Air Force Scientific Adviser
Director Trials

Aeronautical and Maritime Research Laboratory
Director

Research Leader: Dr D.B. Paul
Prof Denys Amos
Dr Wai-Man Lau
Dr J.D. Cotter
Mr C.H. Forbes-Ewan

Electronics and Surveillance Laboratory
Chief, LOD
Dr J. Manton, LOD
Dr N. Curtis

DSTO Library
Library Fishermens Bend
Library Maribyrnong
Library Salisbury (2 copies)
Australian Archives
Library, MOD, Pyrmont (Doc Data sheet only)
James Cook University, Dr R. Griffiths

Capability Development Division
Director General Maritime Development (Doc Data Sheet only)
Director General Land Development
Director General C3I Development (Doc Data Sheet only)

Army

ABCA Office, G-1-34, Russell Offices, Canberra (4 copies)
SO (Science), DJFHQ(L), MILPO Enoggera, Queensland 4051
NAPOC QWG Engineer NBCD c/- DENGRS-A, HQ Engineer Centre Liverpool Military Area, NSW 2174

Intelligence Program

DGSTA Defence Intelligence Organisation

Corporate Support Program (libraries)

OIC TRS, Defence Regional Library, Canberra
Officer in Charge, Document Exchange Centre (DEC) (Doc Data Sheet and distribution list only)
*US Defence Technical Information Center, 2 copies
*UK Defence Research Information Centre, 2 copies
*Canada Defence Scientific Information Service, 1 copy
*NZ Defence Information Centre, 1 copy
National Library of Australia, 1 copy

UNIVERSITIES AND COLLEGES

Australian Defence Force Academy
Library
Head of Aerospace and Mechanical Engineering
Deakin University, Serials Section (M list), Deakin University Library, Geelong, 3217 (
Senior Librarian, Hargrave Library, Monash University
Librarian, Flinders University

OTHER ORGANISATIONS

NASA (Canberra)
AGPS

OUTSIDE AUSTRALIA

ABSTRACTING AND INFORMATION ORGANISATIONS

INSPEC: Acquisitions Section Institution of Electrical Engineers
Library, Chemical Abstracts Reference Service
Engineering Societies Library, US
Materials Information, Cambridge Scientific Abstracts, US
Documents Librarian, The Center for Research Libraries, US

INFORMATION EXCHANGE AGREEMENT PARTNERS

Acquisitions Unit, Science Reference and Information Service, UK
Library - Exchange Desk, National Institute of Standards and Technology, US

SPARES (5 copies)

Total number of copies: 48

Page classification: UNCLASSIFIED

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
DOCUMENT CONTROL DATA

1. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

2. TITLE	3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION)
A Methodology for Measuring the Physiological Strain of Enhanced Soldiers: The 1998 Soldier Combat System Enhancement Study	Document (U) Title (U) Abstract (U)

4. AUTHOR(S)	5. CORPORATE AUTHOR
Denys Amos, James D. Cotter, Wai-Man Lau and Christopher H. Forbes-Ewan	Aeronautical and Maritime Research Laboratory PO Box 4331 Melbourne Vic 3001 Australia

6a. DSTO NUMBER	6b. AR NUMBER	6c. TYPE OF REPORT	7. DOCUMENT DATE
DSTO-TR-0747	AR-010-678	Technical Report	November 1998

8. FILE NUMBER	9. TASK NUMBER	10. TASK SPONSOR	11. NO. OF PAGES	12. NO. OF REFERENCES
510/207/0935	ARM 98/100	DGDHS	94	0

13. DOWNGRADING/DELIMITING INSTRUCTIONS	14. RELEASE AUTHORITY
None	Head, Combatant Protection and Nutrition Branch

15. SECONDARY RELEASE STATEMENT OF THIS DOCUMENT

Approved for public release

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DOCUMENT EXCHANGE CENTRE, DIS NETWORK OFFICE, DEPT OF DEFENCE, CAMPBELL PARK OFFICES, CANBERRA ACT 2600

16. DELIBERATE ANNOUNCEMENT

No Limitations

17. CASUAL ANNOUNCEMENT Yes

18. DEFTEST DESCRIPTORS

Stress (physiology), Physiological effects, Army personnel, Tropical regions, Body temperature, Heart rate, Hydration, Oxygen consumption, Human factors, Combat uniforms.

19. ABSTRACT

The prime objective of the 1998 Soldier Combat System Enhancement Study was to assess, develop and verify methods to evaluate the physiological performance of dismounted soldiers with basic or enhanced capabilities conducting routine operations in the tropics. Core temperature, mean skin temperature and heart rate are appropriate measures for evaluating the physiological burden of soldier combat system enhancements. Current techniques for measuring mean skin temperature and heart rates are adequate. The measurement of core temperature using rectal thermistors has significant limitations, especially during vigorous activities. Studies of the hydration status of soldiers can be conducted using relatively straightforward methods to determine water intake, weight loss, urine production, and total sweat rate by weight differences. For field studies of hydration, there may be no need to analyse urine for sodium; specific gravity is more easily measured and appears to provide adequate information on hydration status. The robustness of the Metamax used for VO2 measurements was demonstrated and provided real time measurements of oxygen consumption, and of metabolic stress associated with activities.

Page classification: UNCLASSIFIED